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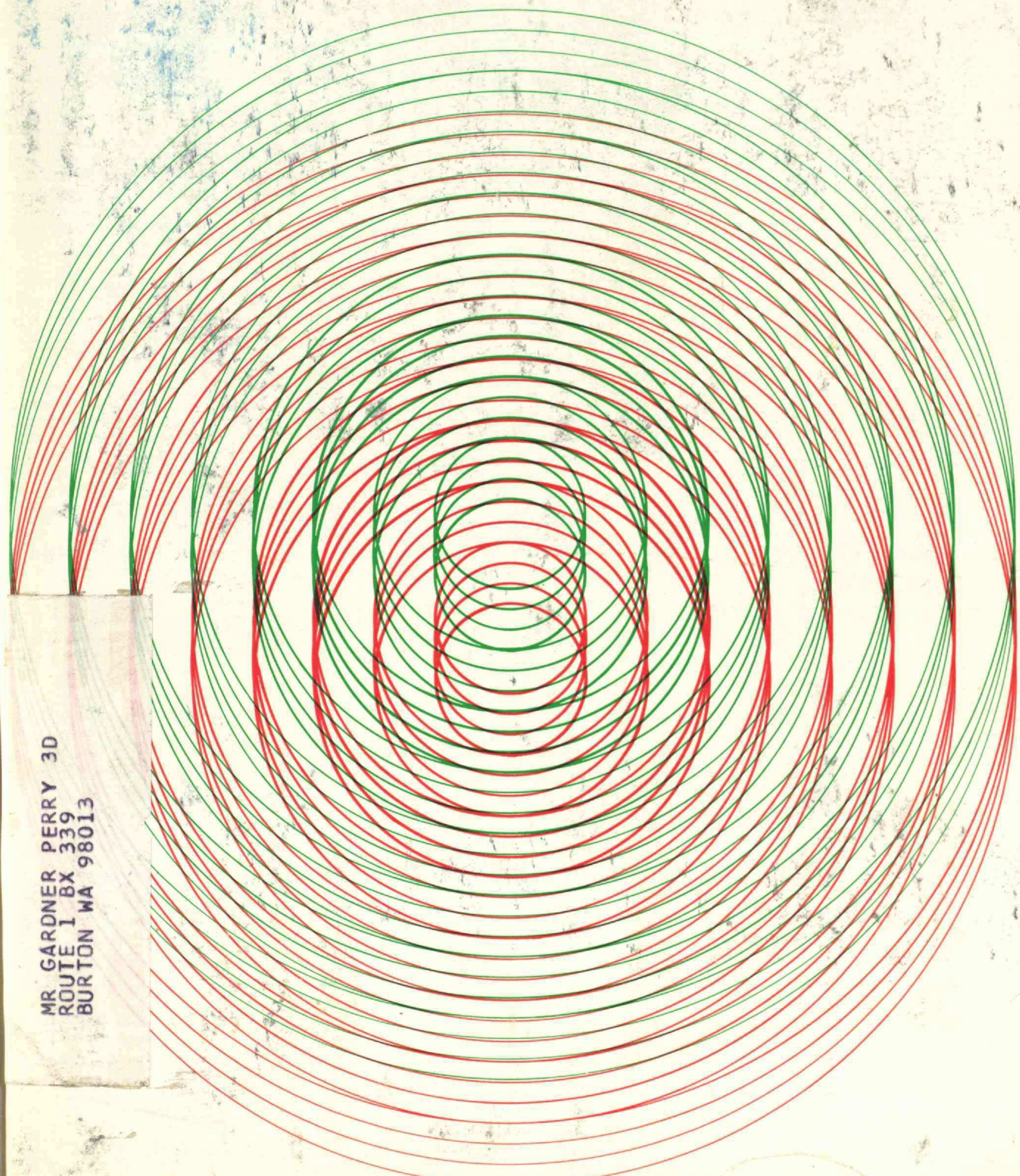
A Special Issue on Cosmology and Astrophysics

Technology Review

Edited at the Massachusetts Institute of Technology



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The First Line


D. Salisbury


C. Norman

A prideful welcome to two new regular contributors in this issue's "front-of-the-magazine" pages: Colin Norman, Washington correspondent for the distinguished British journal *Nature,* and David F. Salisbury, Science Writer for the *Christian Science Monitor.*

Mr. Norman brings a British background to his observations of the American scene: he studied in the Science Department of Manchester University (B.Sc. 1969) and reported for *Nature* in Britain before bringing his typewriter across the Atlantic in 1971. Mr. Salisbury, who has occasionally written for *Technology Review* since joining the *Monitor* in 1972, studied physics at the University of Washington (B.S. 1969); he won the Science-in-Society Journalism Award of the National Association of Science Writers in 1974.

Cosmology and Astrophysics

The five articles in this issue have been arranged for publication by Michael Feirtag — an effort worthy of more approbation than space permits. — J.M.

Letters

Whose Bloody Failure?

It's curious that none of the ten options in William Haddon's "Reducing the Damage of Motor-Vehicle Use" (*July/August, pp. 52-59*) deals directly with the driver as vehicle controller, except for the reference to "attempting to change the public's behavior" (with respect to speed). And the only reference to improving the ordinary driver's skills is to "traditional litanies about 'accident prevention' and 'changing human behavior,' an approach that considerable research and our country's uncounted millions of crashes show to be a substantial and bloody failure."

Yet half the blood must be attributed to alcohol, which — while it is still a driver problem — is less a matter of training and more a matter of law enforcement. Some of the blood is no doubt attributable to equipment failure, and no doubt some of it is attributable to those collisions which no amount of training could have prevented.

But in my 14 years of driving experience, no one has ever taken any steps to measure, much less improve, my skills. I had driver education — a headstart on most of the driving population — but that was optional. That most people can get a driver's license with no training is indeed a failure — not of engineering but of policy. And that failure lies at the doorstep of state legislatures. State legislatures can in general do very little about Detroit (California is a noteworthy exception), but they can do everything about the quality of drivers licensed to operate within their own states. They do nothing. That's where the failure lies.

Lewis W. Flagg III
Chicago, Ill.

Mr. Flagg is Assistant Dean, School of Social Service Administration at the University of Chicago.

Dr. Haddon responds:

Simply stated, the letter misses points, incorrectly presumes others, and incorrectly implies that the issue is "*a* failure" (emphasis supplied). In illustration:

1. The ten numbered options I identified are the *strategies* available for reducing society's bottom-line totals of damage to people and property and the resultant economic impacts. As I stated, the *tactics* with which I illustrated the paradigm were just that, examples for illustration. No suggestion of all-inclusiveness or coverage of all possible or even popular tactics was intended. Indeed, reflection should suggest that quite a few more pages would be required, even if such could be successfully accomplished for a very complex field with many factors operative. Nonetheless, when in 1969 the evidence concerning driver education and training was evaluated, the authors of the report published by the National Academy of Sciences/National Academy of Engineering found the evidence inconclusive, a state of affairs that remains despite additional work of generally poor scientific quality and often contradictory results.

2. Abusive use of alcohol is indeed causally involved in about half of fatalities, and a considerably lower percentage of run-of-the-mill crashes, but careful scientific work has failed to find that very intensive and expensive law-enforcement concentrating on reducing the role of alcohol in many U.S. jurisdictions has thus reduced total fatal crashes in comparison with comparable jurisdictions without such programs. Reductions occurred in the United Kingdom a few years ago after such a program was begun, but the deaths have since returned to the prior trend line despite continuation of the program. Moreover, recent research on Scandinavian (especially Swedish) experience fails to find evidence of effects of the widely-described efforts there. However, a more basic point is missed, as is common. As I also wrote, ". . . the choice of loss reduction countermeasures among the options available must be based on their effectiveness in helping to reduce the end-results in damage — not necessarily on preventing the initiation of the impacts themselves." Since scientifically well-based tactics subsumed under most of the ten strategies are known to work to various substantial extents in reducing several kinds of the losses involved, pushing single tactics of as yet no scientifically-demonstrated efficiency or even efficacy makes no sense on humane, economic, or political grounds.

There was a time when popular folk beliefs dominated discussion of numerous, now largely controlled public health problems, many of major importance: for example, plague, some lead poisoning, cholera, and tuberculosis. As scientific knowledge increased, assertions unbuttressed by carefully collected information were increasingly supplanted by scientifically-informed discourse. This is the transition through which the huge and diverse problem of reducing damage associated with motor vehicle use is now passing. My brief paper was intended as both an illustration of, and contribution to, that change. It is primarily a tool for rational analysis, not an outline for programs. If it is in any way "curious," I believe it is because despite more than *two million* U.S. road fatalities to date and the injured daily averaging more than 10,000, such options analysis is the rarity, not the rule.

Humans vs. Birds, Cont.

Cyrus Adler questions the values of those (he includes me) who would preserve birds from DDT at the expense of vitally needed food production *(October/November, p. 4)*. My article (*"Pesticides and Breeding Failure in Birds," June, pp. 8-9*) was concerned with the relationship between chlorinated hydrocarbons and reproductive success in wild birds, as understood in 1975. The article did not address the causes of death in adult birds, heavy metals, mammals, hazards to man, cancer, India, or malaria. I do not see what these topics have to do with reproduction in birds. If Mr. Adler has a serious theory that thallium or "something else" is responsible for eggshell-thinning or any of the other observed symptoms of reproductive failure in wild birds, I am willing to listen to his evidence and debate with him. But let us confine ourselves to the subject at issue. This kind of irrelevant, irrational, and *ad hominem* attack makes it very difficult to conduct rational discourse, and I think editors who publish letters of this kind do a disservice to their readers.

The Massachusetts Audubon Society has not opposed the export of DDT. I myself have endorsed the use of DDT and other pesticides in cases where the benefits

can be shown to outweigh the risks, including explicitly malaria control in overseas countries. These are simple matters of the public record which Mr. Adler should have verified before committing himself to paper. As it stands, this paragraph is false and defamatory.
Ian C. T. Nisbet
Lincoln, Mass.

Dr. Nisbet is Director of the Scientific Staff, Massachusetts Audubon Society.

The Best of an Imperfect World
In "The High Price of Technology Misused" (*July/August, p. 5*), Kenneth Boulding accepts the fact that socialism is a "gigantic fraud." He does not enlighten us with further facts as they exist in the state-run Communist nations: that individual freedoms do not exist, that man's soul, mind, and body are literally owned by the state. Mr. Boulding fails to realize that what he wants for us, we already have here in America today: individual freedoms unprecedented in man's history, freedoms which Western civilization struggled centuries to achieve, plus a 40-hour or less work week and sufficient time and resources with which to enjoy these freedoms. Our most ever present worry is how to spend the extra time and money: a camper? a boat? a third car? True, not everyone has benefited equally in our society, but why should they?

Corrupt capitalism? Malarkey! Our free enterprise system is certainly no more corrupt than any system that has ever existed on earth for a period of 200 years, and is probably less corrupt than any that has existed for 50 years. As many of us have learned, "Our free enterprise system is not perfect; it's only the best."
S. Parker Gay, Jr.
Salt Lake City, Utah

Wind Power
An addendum to "Windmills in the History of Technology" by Volta W. Torrey (*March/April, pp. 8-10*): The Canadian N.R.C. reported a few years ago a newly designed windmill which consisted of two airfoil ribs on a vertical axis. This was found to be much more efficient as a battery charger or water pump, but has not, as far as I know, been designed for large-scale use.

While the precise control of speed necessary for electrical generation would undoubtedly present a difficult problem, its use on pumps returning water from tail race to head race at a hydroelectric development would be less complicated but equally effective.

In these days of energy shortage, a serious effort to develop wind power applications should be made.
C. H. Conroy
St. John's, Newfoundland

Mr. Torrey responds:
The N.R.C. vertical axis machine was copied at N.A.S.A.'s Langley Research Center and an electric starter was added to get it going without a shove. Since then, a group in New Mexico has tried putting a Savonius rotor above and below the bow-shaped airfoils.

On Blimps, Limp and Otherwise
Joseph F. Vittek, in his article, "Is There an Airship in Your Future?" (*July/August, pp. 22-29*), gives the names and descriptions of the various types of lighter-than-air craft. He says that the blimp was so named because of the sound made when the airship was tapped with the finger. This would accord with the "bow-wow" theory of names.

Many years ago I heard a different, and to me more plausible, derivation. During the first war, the British had a number of different types of such craft. Some were rigid, with a frame to support the gas bag; others were limp, and the inflating gas was used for support. The most popular type of the "limp" was type B, and was designated the "B-Limp." That was too big a mouthful, and so was shortened to plain "blimp."
H. C. Jones
Sub City Center, Fla.

Dr. Vittek errs in his statement, "If [the airship] is 'light,' it will ascend. Because the density of air decreases with altitude, the higher the airship rises, the less the displaced air weighs. Eventually it will reach equilibrium — the airship's 'static ceiling.' "

The French government made the same mistake in 1783, "so that alarm not be occasioned to the people."

My 1930 textbook chapter on aerostatics points out that the density of air and lifting gas decrease in the same proportion as altitude is increased, and therefore the relative lift between them does not change. Positive lift will be maintained, and the aircraft will accelerate upward, until either gas escapes from the appendix or the aeronaut opens his maneuvering valve and lets some gas escape.

If the aeronaut does not interfere, the aircraft's velocity will cause it to ascend above its equilibrium height, until it has vented sufficient gas to halt its ascent. It will then start down, accelerating to its terminal velocity, until it hits the ground. For the reasons just described, aerostatic lift is unstable life, i.e., not self-correcting.

Also for the same reasons, buoyant aircraft cannot make vertical landings unless they carry appreciable ballast on board, which is jettisoned to make them "light" and so, gradually, to halt their descent. Upon reaching the ground, more gas must then be valved to make them "heavy," or they will immediately take off again. Only balloons can safely perform this maneuver. The reaction times for a large airship are so slow that a vertical descent can only be made at extreme peril,
(Continued on p. 13)

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Katherine L. Atwood, Circulation Manager

Science in Government: Slow Steps to Power

Washington Report
by
Colin Norman

Presidential statements on science and technology, being extremely rare events, are always carefully analysed and milked for every drop of significance to the scientific community. Thus much newsprint was dutifully expended on President Ford's latest homily on the importance of research and development, delivered during White House ceremonies honoring 13 recipients of the National Medal of Science. The general verdict is that Mr. Ford went out of his way to rebuild bridges between the Administration and the scientific community which his predecessor dismantled.

He extolled "the benefits of our research efforts to the nation and the world," promised strong support from his Administration for research and development, and noted that civilian science and technology had received a large funding increase this year. And the theme of reconciliation was sounded again by Vice President Rockefeller, who reminded the medalists and some 200 other luminaries from science and government that Mr. Ford has invited scientists back into the White House to help run the nation's affairs.

Though the remarks are welcome salve for some of the wounds inflicted by Mr. Nixon and his lieutenants, the reality behind the rhetoric is unfortunately not so rosy as Mr. Ford would have us believe. The paranoia which characterized the Nixon Administration's dealings with the scientific community has certainly disappeared, and there's a new spirit of détente in the White House. But scientists still have a long way to go before they are restored to fiscal and political favor in Washington. And the problems are not confined to the Executive Branch, for there have been alarming attacks recently on the basic research in Congress.

More Is Less

For a start, let us examine a little more closely Mr. Ford's upbeat remarks about support for civilian research and development. Those activities, he said, received a 12 per cent increase in funds during his first year in office. Well, the fact of the matter is that the Ford Administration's first budget actually reversed a ten-year trend of increases in the share of the federal research and development budget devoted to civilian research. According to an analysis of federal spending published by the National Science Foundation just a few days before Mr. Ford spoke, "the R. & D. total in the budget is the first in the 1966-76 decade that reflects a greater relative increase for the defense/space component than for the civilian component. . . . In spite of a sizeable rise for energy programs, the civilian portion of the federal R. & D. total shows a rate of growth in 1976 well below that for 1974 or 1975, whereas the defense/space portion registers the highest relative increase for any year in the 1966-76 period."

Certainly, in terms of overall expenditures, science and technology have so far fared as well as can be expected under Mr. Ford. Total federal expenditures for research and development are expected to rise from \$18.9 billion last year to \$21.7 billion this year — an increase which, though hopelessly insufficient to keep pace with inflation, is reasonably generous in view of the economy. But again, there are serious questions to be raised about the priorities reflected in the Administration's spending.

According to N.S.F.'s analysis, funding for basic research is expected to increase by only 3.6 per cent this year, while applied research will probably grow by about 8 per cent and development funding by about 20 per cent. If those figures are at all correct, the purchasing power of the basic research budget this year will be some 16 per cent below the 1967 level. Further, in his first budget President Ford suggested a large cut in biomedical research funds for fiscal year 1975, and he proposed a very meager increase for 1976.

It could, of course, be argued that Mr. Ford arrived on the scene relatively late in the 1976 budget cycle, and should therefore share the criticism for its inequities. But, with the Presidential election upon us, and Mr. Ford shoring up his right wing against a challenge from Ronald Reagan, calls for fiscal restraint and massive cuts in federal expenditure are the order of the day. Improvements in the budgetary outlook for basic research should not be anticipated.

A Lukewarm Welcome

As for the proposal to reestablish an Office of Science and Technology Policy in the White House, again public pronouncements emphasize Mr. Ford's enthusiasm for having scientists back in the corridors of power to help on all manner of pressing national problems. But other indications suggest that the matter ranks fairly low among the Administration's priorities.

When Mr. Ford was elevated to the presidency last year, he was greeted with a barrage of advice from many prominent scientists on the need to reestablish the science advisory apparatus which his predecessor abolished. His response, in December last year, was to ask Vice President Rockefeller to study the matter and to make some recommendations. Mr.

Rockefeller, who has a reputation for surrounding himself with bright advisors, and who has strong links with the scientific community, duly recommended that a science policy office should be set up in the Executive Office of the President. Mr. Ford then asked Congress to legislate such an office into existence.

If Mr. Ford had felt a desperate need for a science advisor at his elbow, he could have reestablished the Office of Science and Technology — or something similar — in the same manner that Mr. Nixon dismantled it, by simply issuing an executive order. In that case, the Office could have been functioning a year ago, but instead it is not likely to make much of a contribution to national policy until after the election, at the earliest.

It was widely reported that Mr. Ford decided to ask Congress to establish the Office by legislation because he wanted Congress' views on the matter. But it should be noted that he felt no such compunction when he revamped the White House's energy policy apparatus by creating the Energy Resources Council under the chairmanship of Rogers C. B. Morton. So it is difficult to escape the conclusion that Mr. Ford simply used the congressional route as a convenient dodge against prominent criticism. If that is the case, it does not augur well for the influence of the Office of Science and Technology Policy if, or when, it is established.

Burning Books and Budgets

Meanwhile, on the other side of town, Congress has been displaying alarming hostility toward basic research in general, and the programs of the National Science Foundation in particular. A spate of press releases from a few Senators and Congressmen pouring scorn on some seemingly trivial N.S.F. research projects generated sacks of irate letters from constituents. Since then, strident demands have been voiced in the House for tighter congressional control over N.S.F.'s operations. The demands have more recently distilled to cries for reform of N.S.F.'s peer review of grant applications.

Disregarding the question of whether

(Continued on p. 12)

Can We Protect Ourselves Against Plutonium?

National Report
by
David F. Salisbury

The heavy, hollowed-out hemisphere of plutonium felt unnaturally warm as it lay cradled in my hands. Hidden beneath the gleaming, nickel-plated surface lurked several kilos of some of the most controversial stuff which science has yet created.

When mixed with uranium in reactor fuel, the heat of fissioning plutonium atoms could be the key to several hundred years of plentiful energy. However, if a small band of armed criminals or terrorists were to assemble enough plutonium-235 they could use it for nuclear blackmail, perhaps even fashion it into a crude atomic bomb.

Two armed guards watched me with suspicion as I handed the plutonium shell back to its custodian. They reminded me of why I had come to Los Alamos Scientific Laboratory, the "home" of the atomic bomb: I hoped to discover how large quantities of plutonium can be handled safely and securely.

Nagasaki, 1945. (Photo courtesy of International News Photos.)

When the United States and the world begin relying heavily on fission reactors in the petroleum-short future, thousands of pounds of this artificial element will be created, processed, stored, shipped, and burned as nuclear fuel.

Since the beginning of the energy crisis, President Nixon and now President Ford have insisted that the rapid expansion of America's nuclear industry is essential to reduce U.S. dependence on foreign oil. And without plutonium, rapid nuclear growth is not possible.

This pressure to develop nuclear energy has stirred up an active anti-nuclear campaign across the country, particularly in the West. A petition (signed by Nobel laureates Linus Pauling, Harold Urey; and Hannes Alfven) calls for a series of stringent safeguards on nuclear energy. The petition, now being circulated by a coalition called People for Proof, has garnered enough signatures in California to qualify for the next ballot. The People's lobby has begun passing it around in Washington and Oregon, and they plan to move soon into the midwest.

Roadblock to Nuclear Power

There is only one new element in the complex, emotion-laden issues surrounding nuclear energy; most have been around since the first attempts to use the atom for peaceful purposes. Only the possibility that terrorists might seize nuclear material and use it to make a bomb is relatively new. Yet today a number of observers feel that this risk of nuclear theft represents the most troublesome danger created by increasing reliance on nuclear energy.

While continuing to downplay the issue in public, government officials and some leaders in the nuclear industry are taking the matter extremely seriously. "One of the real dangers" is how William Anders, Head of the Nuclear Regulatory Commission (N.R.C.), describes it.

As a result, the design of the Gulf Atomic fuel reprocessing plant being built in Barnwell, S.C., incorporates a number of sophisticated security devices, and more secure methods for shipping strategic nuclear materials are under development at Sandia Laboratories in Albuquerque. Los Alamos scientists are putting together a real-time computer-controlled accounting system which will keep track of plutonium as it is separated, stored, and processed into nuclear fuel.

These steps are being taken despite the fact that there is still disagreement about how successfully terrorists could fashion plutonium or highly enriched uranium into a bomb. Dr. Theodore Taylor says it is relatively easy to make a crude bomb. He is the weapons expert who brought this issue to the public because the Atomic Energy Commission and members of the nuclear industry refused to take his concern seriously when he explained it to them privately. Other weapons experts argue that the chances that an amateur's atomic bomb would explode are slight.

Yet even the slightest possibility is enough for blackmail. What official could take the chance that a terrorist bomb planted in Washington, D.C., would fail to detonate? Already there has been one nuclear bomb threat in the U.S.; in 1970 city officials in Orlando, Fla., received a note demanding \$1 million on threat that the city would be blown apart by a hydrogen bomb. A drawing of the device was included.

Neither the Atomic Energy Commission nor the F.B.I. could assure the city fathers that the threat was a hoax. The officials were seriously considering paying the sum until the would-be bomber — a 14-year-old honors science student — slipped up and was caught by the police.

The Commission could not give assurance that the threat was not real because significant quantities of plutonium and enriched uranium have apparently gone unaccounted for in the past. One of the strongest indications that this is the case are the official refusals, for "national security reasons," to disclose the amount of "Materials Unaccounted For" at various sites. If these shortages are consistent with

the statistical uncertainties in the inventorying process, it is hard to account for such reluctance.

Can improved physical security methods prevent blackmail threats in the future? Dr. Taylor, for one, feels that such methods can in fact be developed, and can make nuclear energy, in the United States at least, "reasonably safe."

However, he agrees with two other experts on the subject — Rudolf Rometsch, who is the Inspector General of the International Atomic Energy Agency, and Carl Walske, a former Pentagon weapons safety advisor now heading the Atomic Industrial Forum — that reliance on nuclear energy carries an inescapable risk: sometime in the future terrorists probably will steal enough plutonium to construct a clandestine atomic bomb. But even when that happens, "civilization won't collapse," says Dr. Taylor. He and his colleagues argue that people must face up to this eventuality and balance it against the large amounts of energy which nuclear reactors can provide.

What Price Energy?

Yet when does the risk become "unreasonable"? Dr. Taylor thinks that nuclear energy might not be worth one terrorist atomic bomb exploded every ten years. Walske says he does not think society could stand clandestine explosions more than four times a century. Though he admits to "many sleepless nights" over the question, Dr. Rometsch comments that he is often surprised by how much people will accept.

No matter how stringent the safeguards, there can be no absolute assurance that a nuclear theft will not occur. However, the record of airport security measures in preventing the hijacking of jetliners suggests a particular course of action can be made so difficult that terrorists whose aim is to draw attention to their cause and to apply force on national leaders will pick easier targets.

Can such a successful security system be set up for nuclear materials? Every industry spokesman argues that it can; however, nuclear facilities around the country have adopted tighter security only when ordered to by government regulators. And physical security measures at industry laboratories handling plutonium and enriched uranium leave much to be desired. At one laboratory I recently visited there was only one armed guard. Access to the areas which contain plutonium was through two remote unlocked steel doors which did not appear capable of withstanding high explosives. Plutonium was stored in a series of small vaults, any one of which could have been hauled away with a small cart.

Members of the Nuclear Regulatory Commission are talking about postponing the mixing of plutonium into reactor fuel until methods for guarding the fuel can be agreed upon and put into operation. "There has been a great deal of talk," says Dr. Taylor, "but the physical safeguards today are still inadequate."

David Salisbury is Science Editor for the Christian Science Monitor, *and recipient of the 1974 science writing award of the National Association of Science Writers. With this, the first of two columns on the problems of protecting nuclear materials, he becomes a regular contributor to* Technology Review.

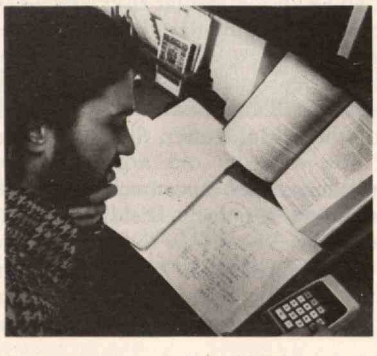
M.I.T. Student Designs Atomic Bomb

For any experts who doubted the ability of a terrorist to construct a nuclear weapon from stolen plutonium, the public television science program, *Nova,* dropped a considerable bombshell last March.

In the installment titled "The Plutonium Connection," it was explained how a 20-year-old chemistry student from an "eastern institute of technology" had used easily-obtained scientific information to design a nuclear bomb from scratch in five weeks. If anyone wondered where this "eastern institute" was, they were answered by such newspapers as the *New York Times,* which identified M.I.T. as the "famous university in Boston" alluded to in the program. The Institute has long been known for its tongue-in-cheek "atom bomb club," so it was a natural place for *Nova* producers to look for a bomb builder.

The bomb was designed to be built from stolen plutonium and parts from any hardware store, using information from M.I.T.'s libraries and the National Technical Information Service in Washington, D.C.

"I was pretty surprised at how easy it is to design a bomb," said



An actor portraying the M.I.T. student atom-bomb designer on the public network television program, *Nova*, displays his design.

the actor who impersonated the M.I.T. student on television. The student remains anonymous for obvious reasons. "When I was working on my design, I kept thinking, 'There's got to be more to it than this.' But actually there isn't too much to it."

The bomb had a "fair chance of working," testified a weapons expert from the Swedish Defense Ministry on the program — yielding "probably less than 0.1 kiloton" of T.N.T.

He called the student's work a "shocking" report. — *D.M.*

Measuring Cancer Hazards: It Takes a Mouse to Catch a Rat

Technology/Environment
by
Ian C. T. Nisbet

U.S. restrictions on the use of chlorinated hydrocarbon pesticides and PCBs have been based almost entirely on assessment of the hazards they pose to human health. The Environmental Protection Agency cancelled agricultural uses of DDT in 1972 because of the potential cancer risk to man. The hazard of cancer was the only basis for the subsequent ban on the manufacture and use of aldrin and dieldrin. And cancer is again the only risk being considered in the ongoing hearings on heptachlor and chlordane.

The aldrin-dieldrin case, decided by E.P.A. in 1974, is especially illuminating because the scientific issues were clearly posed and fully debated. (The two chemicals were considered together because aldrin converts to dieldrin in the environment and so poses similar risks.) By 1974 there was no dispute that dieldrin induces cancer in laboratory mice: this was demonstrated repeatedly in well conducted experiments, many of which were carried out by the manufacturer, Shell Chemical Co. Nor was the old argument that "everything causes cancer at high enough doses" taken seriously. Dieldrin had induced cancer in mice at the lowest dose ever tested: one-tenth of a part per million in the diet, not drastically higher than background environmental contamination.

The principal issue presented and resolved at the hearings was whether the induction of tumors — specifically, the induction of liver tumors — in mice was a valid predictor of carcinogenic hazard to man. The issue underlay regulatory decisions on DDT and other chemicals, and threatened broad repercussions. Health agencies in many countries recommend mice for routine testing of pesticides, food additives, and drugs. If the argument that "mice are of no value for carcinogenicity testing" were accepted, the existing regulatory system would have been pitched into chaos.

Of Mice and Men

Briefly stated, Shell's arguments were that dieldrin induces cancer only in the livers of mice; that it does so by mechanisms unique to the species; that the mouse liver is especially sensitive to chemicals and unpredictable in its responses to them; that dieldrin is inactive in other species; and finally, that the experience of human safety over 20 years of use should outweigh any doubts raised by experiments on mice.

To consider the last argument first, one key characteristic of chemical carcinogenesis is the long latent period elapsed between exposure to the cancer-causing agent and the overt manifestation of its effect as a tumor. Except in cases of very intense exposure, this latent period in both mice and man is typically at least half a lifetime. Even in the case of cigarette smoking, which constitutes a fairly intense exposure to a number of carcinogens, the latent periods for development of lung and bladder cancers in man are on the order of 20 and 30 years respectively. So it is still too early to expect observable consequences from human exposure to dieldrin, which did not begin until the 1950s. As we have learned from the research history of smoking, before direct evidence for the carcinogenicity of an environmental chemical can be obtained, an entire generation will have been exposed.

In any case, epidemiological studies in the general population are essentially impossible. Because we are all exposed to dieldrin in our food and by other routes, there is no unexposed group (analogous to non-smokers) available for statistical comparison. As evidence of safety, Shell pointed to the low incidence of cancer in workers occupationally exposed to aldrin and dieldrin in the manufacturing plant. However, the group of workers under study was extremely small — only 69 had more than 10 years' exposure — and the degree of exposure (as measured indirectly by levels of dieldrin in the blood) was not enormously greater than that in the general population. Although the study might have revealed positive evidence if dieldrin were an extraordinarily potent carcinogen, its value as negative evidence is almost nil.

The routine use of rats and mice for carcinogenicity testing is scientifically justified by the similarity in the effects of carcinogens in these rodents and in other animals, including man. All the chemicals known to cause cancer in humans (with the exception of arsenic, still under study) also cause cancer in experimental animals. Even the mouse liver, recently under vigorous attack by industrial toxicologists, has proved to be a good predictor of carcinogenic effects in other species. Of 50-odd chemicals which are known to induce cancer in the livers of mice, only two have been tested with negative results in rats: these are 2-naphthylamine (a known carcinogen in dogs and humans) and phenobarbital (whose record of safety as a human drug is at best equivocal).

The notion that the mouse liver is "labile" and "unpredictable" rests on the fact that some strains of mice develop liver tumors spontaneously at a high and variable frequency. The incidence of these spontaneous tumors is known to depend on many factors including sex, diet, nutritional and hormonal status, and environmental conditions. Accordingly, it is postulated that these spontaneous tumors are in fact caused by unknown environmental factors, and that chemicals which "merely" increase their frequency should not be classified as cancer-causing. However, it is difficult to see the relevance of these arguments to hazard evaluation. It is now well-known that cancer is a multicausal, multi-phased process in which genetic, hormonal, and environmental factors play varying roles. It seems perverse to insist that a single factor must be identified as the sole "cause" before it can be considered a hazard. In any case, humans as well are subject to a high spontaneous incidence of cancer which varies with environmental conditions: we should be just as concerned with an agent that "merely" increases the frequency of a common type of cancer as with one that induces a unique type.

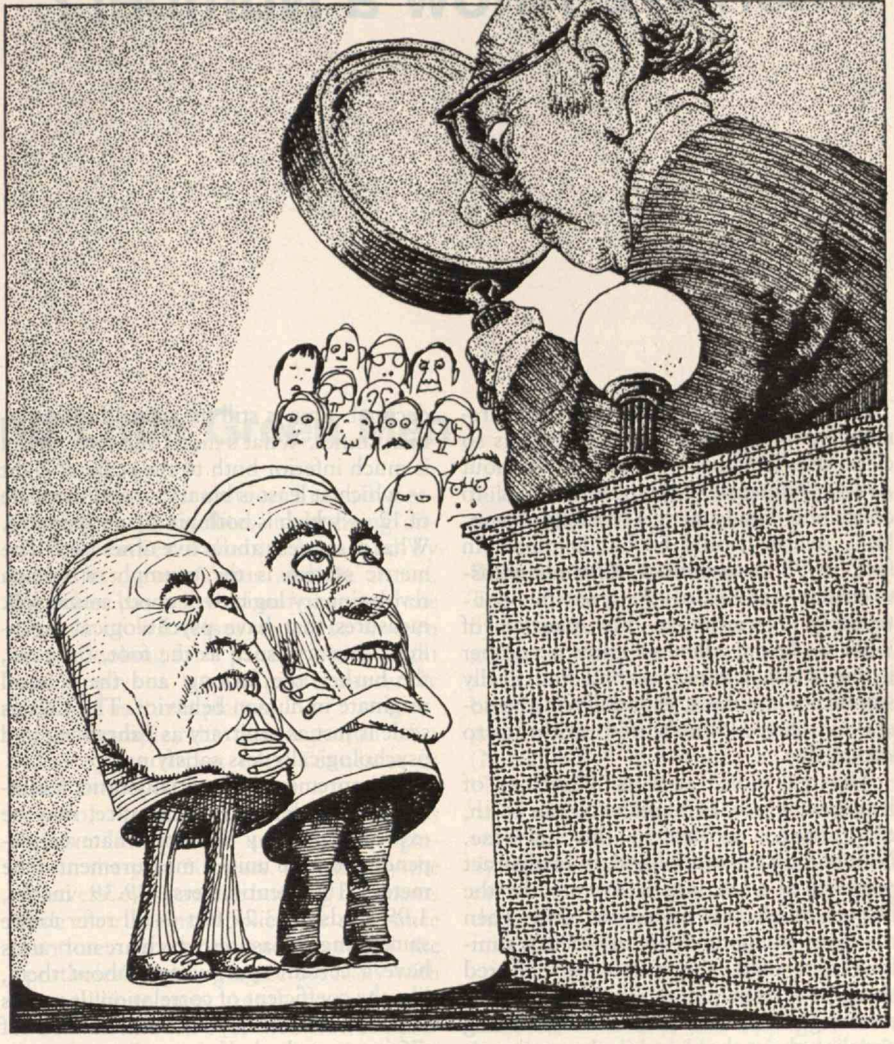
Further, the carcinogenic effects of dieldrin are manifested not only in mice but also in rats. In three separate experiments in which rats were exposed to low doses of dieldrin, the spontaneous incidence of tumors was increased two- to ten-fold. However, because of the relatively small numbers of animals used and

their division into a number of still smaller sub-groups, even these large increases were only just statistically significant. (This graphically illustrates the insensitivity of carcinogenicity tests, which can only reveal large effects unless prohibitively large numbers of animals are used.) Another complication was that the increased numbers of tumors were spread over several sites, including the lungs, thyroid, and breast as well as the liver: this raised the difficult statistical problem of multiple comparisons. Further, the total incidence of tumors declined again among rats tested at higher doses, reflecting the effects of chronic toxicity which shortened their life-span and inhibited tumor development. Because of these complexities, the administrator of E.P.A. accepted the results of the rat experiments only as probable, basing his finding of imminent hazard to human health primarily on the results with mice.

When is the Risk Acceptable?

In a rational world, the finding that a chemical poses hazards to health would be followed by a risk-benefit analysis to determine whether any or all uses pose unacceptable risks. However, cancer poses special problems in this regard. Cancer experts are understandably reluctant to make quantitative estimates of human risk given the enormous variability in response to carcinogens, both between species and between individuals. In principle, no dose of an established carcinogen is so low that it can be assumed to be without effect on susceptible individuals.

In the case of dieldrin, there is little doubt that the risks were high: the exposure of the general public to dieldrin is only a little less than that of the mice and rats whose incidence of cancer was markedly increased. On the other side of the coin, the benefits offered by continued use of aldrin and dieldrin were comparatively modest. In almost all cases, alternative pesticides were available and effective so that the net impact of their suspension was only the small differential in costs. Accordingly, it was relatively easy to reach a qualitative judgment that potential risks far outweighed potential net benefits.



The Environmental Protection Agency's decision to ban use of the chemical pesticides aldrin and dieldrin in 1974 came only after the resolution of an issue crucial to research: whether the results of laboratory experiments on mice can predict the experience of man in the environment. The E.P.A. decided they can. (Reprinted from *Audubon*, National Audubon Society ©1973.)

This judgment was qualified, however, in one important respect. One substantial use of dieldrin — underground use to combat termites — was exempted from the ban. Although the reasons for the exemption were not spelled out fully, it is evident that the very large economic benefits accruing from termite control were judged to outweigh the unknown and unquantified risk that dieldrin injected underground beneath houses might migrate upwards and lead to significant human exposure. An analogous exception had been made in 1972, when uses of DDT for emergency public health purposes were exempted from the general ban on agricultural uses. Here the unquantified benefits of controlling disease vectors in a hypothetical emergency were presumably weighed against the unquantified risks of cancer. Each of these judgments may have been reasonable, but each seems to have been made subjectively, without any formal risk-benefit analysis. But some time soon, a decisionmaker will be forced to grasp the nettle and make an explicit judgment that a certain number of excess cancers in the human population constitutes an acceptable risk.

Ian C. T. Nisbet, who writes regularly for Technology Review, *is a member of the Scientific Staff of the Massachusetts Audubon Society. His Ph.D. (in physics) is from Cambridge University.*

What Do We Know When We Know a Number?

Technology/Society
by
Kenneth E. Boulding

The centrality of numbers and measurement in the development of science is so clear that it needs no defense. Without Arabic numerals, which enable us to count indefinitely using a fixed set of symbols, science would be handicapped. In fact, in 99 cases out of 100 only measurement can resolve scientific controversy. Nevertheless, the question of what we know when we know a number is not trivial. It is easy to find statistically significant numbers, especially in the social sciences, which add nothing to knowledge.

The real world consists of sets — of leaves on a tree, of humans on the earth, of hydrogen atoms in the universe. Number, on the other hand, is an abstract property of a set, largely invented by the human mind. It is interesting only when the items enumerated are sufficiently similar. Even then, the number of all red things, for example, is remarkably uninteresting unless we can find something peculiar about that band in the spectrum. A few numbers may be part of the stuff of the universe — 0, 1, π, and e — but apart from these, one suspects the universe could get along remarkably well without anybody counting or measuring it.

Most numbers are not only artificial but also arbitrary. The decimal scale has no scientific justification: we count in tens simply because we have ten fingers and toes. And measurement is equally arbitrary. The metric system is a preposterous historical accident, with very little to recommend it but popularity. Its units are arbitrary and it is not even consistently decimal: time is still measured in Babylonian sixties. What's more, the scale of ten is much inferior both to the scale of eight — which at least is binary — and the scale of 12 — which is both binary and ternary. What is so great about five times two? The metric system is the triumph of French revolutionary logic over good, sound folk measures that have psychological meaning. Measures such as the foot, the yard, the bushel, the furlong, and the acre all originate in human behavior. The Celsius scale is just as arbitrary as Fahrenheit and psychologically less satisfying.

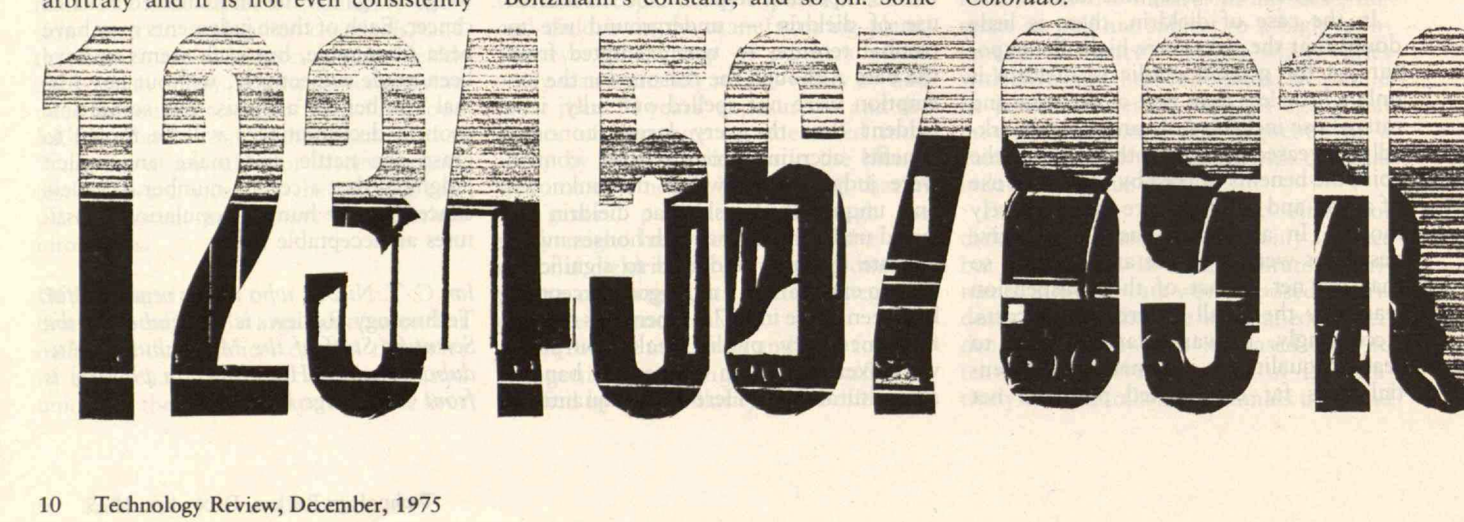
Measurement is essentially ratio. Exactly the same length, for instance, may be expressed by any number whatever, depending on the unit of measurement. One meter, 100 centimeters, 39.39 inches, 1.09 yards, or 3.27 feet — all refer to the same thing. Measures which are not ratios have a certain spuriousness about them, like the coefficient of correlation. It makes no sense at all to say that a correlation of .75 is one and a half times as great as one of .5. Indices are spurious as well. The GNP, for instance, is a vast set of heterogeneous commodities and services which changes in composition as well as structure. When it goes up, we are not quite sure what has gone up. It is not that these numbers are useless; it is just that they should not be taken for more than they are — rough substitutes for an immensely complicated reality.

There are, of course, non-arbitrary quantities in the universe — the speed of light, the gravitational constant, Boltzmann's constant, and so on. Some people have attempted to do physics using these natural units. But their efforts seem to have been more successful than popular. Certainly those terms seem awkward for human measurement, although Bartlett has pointed out that they make more convenient multiples of the English units than they do of metric units. One can hardly imagine being taken to court for driving at 0.000000117 the speed of light.

The psychology of numbers and measures has received surprisingly little attention. Why, for instance, do we bother with decimals in monetary units? Why not a monetary unit like the Italian lira, small enough so that it needs no decimals or cents? Inflation, of course, may give us this unit in 25 years as it gave Italians the lira! Should the optimum unit of measurement be the just noticeable difference, or JND, in each case or is this too variable, or too small for convenience? Which numbers and measures do we easily visualize and which remain obscure? Are there any natural psychological units, as there may be natural physical units? These are questions worth investigating.

The rest of the world is probably right to bully us into adopting the metric system since it's convenient for everybody to tell the same lies. But let us not pretend that the metric system has any scientific foundation and let us not give it the benediction of the scientific community.

Kenneth E. Boulding is Professor of Economics and Director of the Institute of Behavioral Science at the University of Colorado.



Book Reviews

Of Flying Saucers and Little Green Men

UFOs Explained
Philip J. Klass
New York: Random House, 1974, 369 pp., $8.95

Reviewed by James E. Oberg

How can UFOs be explained? If they are interstellar spaceships from another planet or planetary system, a single incident accompanied by some sort of physical evidence would be sufficient proof. But suppose instead that UFOs are not spaceships but in fact only misinterpreted natural or manmade phenomena, hoaxes, or frauds? Must every single case of the tens of thousands of reports filed since 1947 be completely explained?

Philip Klass, an electrical engineer, pilot, and investigative reporter for *Aviation Week* magazine, maintains that UFOs really are the result of misinterpretation and fraud. His book, in proof of this theory, is one of the most important ever to appear on UFOs and goes a long way toward explaining this puzzling and exciting subject.

Doubtful Guests

But what about the reports of "flying saucers" that have deluged us in the newspapers, movies, and on television? Lights in the sky, disk-shaped craft, mysterious effects on radios and motors, landing-pad prints, eyewitnesses to meetings, kidnappings, and little green men: what explanation could be simpler than that the earth is being visited by spaceships from another world?

Since most UFO reports are visual observations, Mr. Klass begins with a methodical study of what people think they see in the sky compared with what they do see. Trial lawyers may have practical experience with eyewitness testimony, but UFO sightings do not seem amenable to such analysis. So Mr. Klass conducts a controlled experiment that allows him to study UFO sightings with unequalled depth and scope.

Many events in the sky can serve as "experiments": meteor fireballs, reentering earth satellites, night-flying aircraft, weather balloons launched by pranksters, even Venus and the moon. Mr. Klass has collected and examined the reports of witnesses to these known events, looking for a pattern which might also apply to UFO reports currently classified as "unexplained."

For example, the disintegration of a Soviet space rocket over Tennessee in 1968 produced reports of a UFO with rows of illuminated portholes, reports very similar to other unexplained sightings in the past 20 years. Apparently the observers' eyes saw the burning fragments while their brains supplied the rest, since the time, direction, and speed of the "portholes" sighting agree precisely with the satellite re-entry. Another case, known to be a meteor fall over the Midwest, produced excellent photographs (shown on the cover of the book) and also some reports from airline pilots of "near collisions" with objects which were actually more than 100 miles away. No one, Mr. Klass concludes, can accurately judge the distance (and hence the size and speed) of a shapeless light in the sky.

Two other patterns emerge from this study, and they are indeed familiar ones. The falling meteors were observed to "veer off" and "curve away" by many witnesses, suggesting "intelligent behavior." A Seattle pilot, startled to fly through a squadron of battery-lit balloons (launched by pranksters), insisted that UFOs were flying at more than 1,000 miles per hour and maneuvering around his plane in an intelligent manner. When the teenage culprits confessed to the prank, the pilot still insisted that the objects were flying saucers, allowing the newspapers that had splashed the mystery on their front pages to equivocate on page 12: "Balloons . . . or not? UFO views vary." So Mr. Klass concludes that ". . . the news media are usually not interested in devoting time or space to a prosaic explanation — especially if it might prompt readers or viewers to conclude that the media had failed to probe deeply enough before reporting the original incident."

Skeptics and Believers

The only available physical evidence of flying saucers are the thousands of photographs of lights and discs in the sky. Their sheer volume has impressed the public. But the President of the National Investigations Committee on Aerial Phenomena (N.I.C.A.P.) admitted in 1972 that "N.I.C.A.P. has never analyzed a structured object picture that is fully consistent with the claim [that] an extraordinary flying device was photographed. . . . In every case, there has been [something] that raised the suspicion of a hoax or a mistake."

Americans have managed to catch on film such sudden and transitory events as meteors, tornados, and falling aircraft. No photographs which satisfy N.I.C.A.P., which actively seeks definitive proof of the existence of extraterrestrial spaceships, have ever been made. Mr. Klass illustrates how easy it is to fake a UFO photo, and reports cases where his investigations uncovered frauds which N.I.C.A.P. had accepted as possibly authentic.

One marvelous case study reveals the depth of Mr. Klass's detective work. The public might assume that professional UFO investigators (most are "believers") carefully probe incidents before endorsing them, but this may not be so. For example, the crew of an RB-47 aircraft flying over Texas in 1957 reported radar peculiarities and visual sightings, convinced that they were being followed by a flying saucer. UFO investigators called it a "classic case," one which illustrated "an unquestionably strange phenomenon." It took some dogged homework and 30 pages in the book to reveal the more earthly explanation which was readily accepted by the crewmen involved. And the same investigators who had praised the RB-47 case as "classic" shrugged off its solution saying that Mr. Klass had "picked an easy one."

How then can the investigator explain

UFOs without explaining every single UFO sighting, an effort that would demand the full-time work of a dozen skeptics? Mr. Klass decided to concentrate on what UFO believers selected as their "best cases," chosen in response to a contest sponsored by *The National Enquirer.*

Put Your Money Where Your Mouth Is

Here the explanations become less precise, and definitive proof of fraud or mistake is lacking. But even in these "best" cases, Mr. Klass uncovers suspicious situations and even cases of outright dishonesty on the part of alleged impartial UFO investigators.

For instance, why was it left to Mr. Klass to reveal that the psychiatrist who treated Barney and Betty Hill (*The Interrupted Journey*) never for a moment believed that they had been inside a flying saucer, while *Look* magazine used his misquoted words as an endorsement? Why didn't some other investigator discover the suspicious nature of the lie-detector test passed by Charles Hickson following the Pasagoula "kidnapping," and Mr. Hickson's desperate financial situation just prior to the incident? Why didn't someone else report on the glaring contradictions in the Socorro and Aurora "landings," and the fact that both occurred in dying towns desperately in need of publicity and tourists? In sum, Mr. Klass suggests that UFOs are good for media sales, for the emotions of people who want to believe in a superhuman civilization which will rescue us from our terrestrial troubles, and for a small, closed fraternity of "experts" who make good livings off lectures, books, consultations, and congressional testimony.

Mr. Klass closes his book with a challenge to believers to "put their money where their mouth is" by signing a contract wager. When certain straightforward criteria are met proving the existence of extraterrestrial spaceships, the author will pay the contender $10,000. Until that event occurs, Mr. Klass must be paid $100 every year up to ten years. Only three people, but not one of the experts making thousands of dollars from books and radio shows promising imminent landing have agreed.

The silent response to this bold challenge is perhaps the best proof that those "experts" who know most about UFO sightings also know that none of them is valid, that the earth is not about to be visited by extraterrestrial spaceships. But the rest of us are left with the sound and fury of sensational media coverage, questionable photographs, and testimony of UFO experts, and we continue to wonder if there might indeed be something to the fuss after all. Mr. Klass's book is for any who are uncertain.

James E. Oberg is a computer specialist in the Space Shuttle project at N.A.S.A.'s Johnson Space Center in Houston. The views expressed are his own and do not necessarily reflect those of N.A.S.A.

Norman

Continued from p. 5

N.S.F. is due for some reform (that would require a separate article), it is easy to agree with Philip Handler, President of the National Academy of Sciences, that the House has at times displayed a "book-burning attitude" in its attacks on N.S.F. Moreover, with little notice in the popular press, Congress has cut more than $41 million from N.S.F.'s 1976 budget request, the largest portion from basic research support.

It is ironic that, while Congress is eager to scrutinize N.S.F.'s $700 million budget, it is not much disturbed by an arrangement by which the Department of Defense funds nearly $1 billion of research in private industry with virtually no congressional control. Independent research and development funding has been under investigation by the Senate Armed Services Committee and roundly denounced by Admiral Hyman Rickover as a waste of taxpayers' money. But since the entire defense industry is behind it, the funding is not so easy a target as N.S.F.'s research projects

Be that as it may, there have been a few hopeful events in science and government during the first year or so of the Ford Administration. After a period of shake-down, the Energy Research and Development Administration is beginning to forge the basis of a national energy research and development policy. The Nuclear Regulatory Commission has demonstrated surprising toughness and independence in its dealings with the nuclear industry. A presidential commission is taking a hard look at biomedical research policy, and to judge by its early actions, it may help to solve some of the problems in that troubled area. And the House of Representatives has streamlined some of its committee jurisdictions so that it can handle science and technology matters in a slightly more coherent manner.

But, in spite of friendly overtures from the Ford Administration to the scientific community, it is premature to conclude that scientific affairs are back on an even keel in Washington.

Colin Norman was graduated from Manchester University in England with a B.Sc. in 1969. He has been Washington Correspondent for Nature *since 1971, and becomes a regular columnist for* Technology Review *beginning with this issue.*

Letters

Continued from p. 3

in an emergency. It follows that airships are not, and can never be, VTOL aircraft. They can only rise vertically.

Dr. Vittek is also wrong when he writes that past rigid airships of the 1930s had pressure heights "of 5,000 to 6,000 ft." They were essentially sea level airships. They had to sacrifice gross lift in the ratio of about 1 per cent per 300 ft. of altitude to cruise in equilibrium at any altitude above sea level. This sacrifice of lift, plus the ballast requirement, are two of the basic liabilities not inherent in any other form of commercial transportation.

Walter P. Maiersperger
Monterey, Calif.

Mr. Maiersperger is Lt. Col., U.S.A.F., Ret.

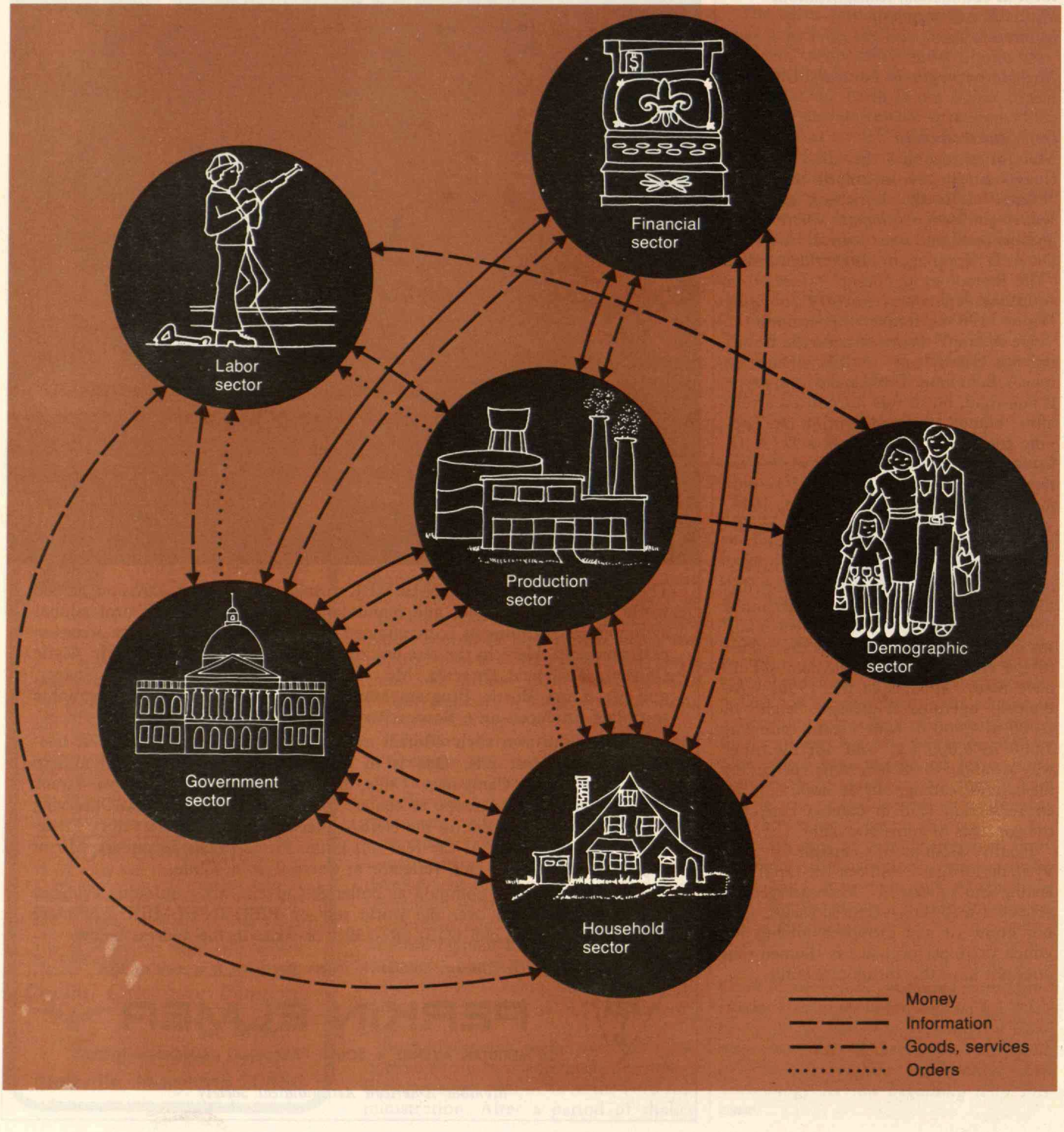
Dr. Vittek responds:

Mr. Jones recounts the most popular theory of the evolution of the word "blimp." It is the derivation given in *Webster's New Collegiate Dictionary,* and the one I find most logical. However, Dr. A. D. Topping, in his excellent article "The Etymology of 'Blimp'" (*American Aviation Historical Society Journal,* Winter, 1963) effectively undermines the "type B, limp" theory because the British did not classify any of their airships as type A, B, or limp. The U.S. did have a type B non-rigid, but it was introduced a year after "blimp" appeared in print. Dr. Topping goes on to document how Lt. A. D. Cunningham, R.N. coined the word after tapping the side of the airship SS-12 during an inspection on December 5, 1915. This event is the one mentioned in my article.

Mr. Maiersperger's note on aerostatics is quite correct. I did not develop this theme fully because of the nontechnical nature of the article. Also, there was a lapsus in the section on buoyancy that added to the confusion. The statement should have read "Airships of the 1930s were typically operated at pressure heights of 2,000 to 4,000 ft. with a static ceiling of 5,000 to 6,000 ft.," and not the other way around. I thank Mr. Maiersperger for his careful reading, but do hope that the entire section read in context conveyed the concepts of aerostatic flight.

Finally, airships are capable of total VTOL performance without the rapid ballasting and valving Mr. Maiersperger describes if they have vectored thrust. I do not know of any proposed airship for which VTOL performance is claimed that does not have this thrust capability.

Trend of Affairs



Trends This Month

PLANNING 15

Intelligent decision making; or, to spiderize the fly.

AUTOMATION 16

People are more than dial watchers . . . the point is proven by performance. . . . Is a programmable mechanical manipulator really a robot?

ENERGY 19

Run cars on coal . . . heat houses with ice.

PHYSICS 21

When is a monopole not a monopole? . . . To create an excited cigar-shaped nucleus.

The six major sectors in the national model of the economy, now being developed by Professor Jay Forrester and his colleagues.

PLANNING

The National Model

Economists have long known that the economy is no string of causes and effects, but an intricate three-dimensional web of variables. Unfortunately, until now man's relationship to that web has been more that of a fly than a spider. Especially today, we feel trapped in the threads of inflation, unemployment, recession, scarce resources, urban decay, environmental damage, population growth, and government instability.

Jay Forrester, Germeshausen Professor of Management, and his colleagues at M.I.T. believe they may have found a way to spiderize the fly; they are constructing a massive computer model of socio-economic change in the United States. They hope it will be used in the next few years as a tool for making public policy decisions.

Professor Forrester is both well-known and controversial for his other computer models, including those of industry, urban development, and, finally, his limits-to-growth model of the world. The models share a reliance on the principles of system dynamics. That is, basically, they attempt to represent in the computer the complex feedback relationships among variables in a social system by mimicking the real system, rather than by resorting to external theories about the system. They portray the way in which real decisions, such as pricing, savings, and government spending, are made on the basis of goals and policies of business, households and government.

A Massive Undertaking

Professor Forrester's National Model is gigantic — several hundred to a thousand times larger than anything the group has yet attempted. Before a discussion of the underlying philosophy, a brief look at the nature of this National Model:

The model is composed of six basic sectors — *production, financial, household, demographic, labor,* and *government (see diagram).* The sectors communicate to one another flows of information, people, money, goods, services, and orders. For instance, as population levels change in the demographic sector, so will the numbers of workers moving to the labor sector, and this will affect the results going from the labor sector to other sectors. These flows are "conserved" just as they are in real life, with nothing "disappearing" in the system without being logically accounted for.

— The *production* sector is the most general, being applicable to capital goods, building construction, agriculture, food processing and distribution, resources, energy, services, transportation, secondary manufacturing, knowledge, education and research, and consumer durables.

— The *financial* sector includes three aggregate financial institutions: the Bank, the Savings Institution, and the Monetary Authority. It serves as a repository for savings and demand deposits, and responds to demands from businesses and households for loans. The sector also generates monetary policy.

— The *demographic* sector generates population size and age distribution, determines the mix of laborers and professionals in the workforce, and generates demand for higher education.

— The *household* sectors (one for labor and one for professionals) allocate individual family resources between savings and consumption. They also allocate the individual's time between participation in the paid workforce, production of goods and services in the home, and leisure activities.

— The *labor* sectors (one for blue-collar labor and one for professionals) circulate workers among the production sectors. The labor sectors produce realistic responses to changes in wages, transfer payments, labor-force participation, and demand for labor.

— The *government* sector generates government purchase of goods and services, provides for national defense, collects taxes, manages fiscal policy, and determines support payments to individuals.

From all these sectors come measures of production, consumption, investment, employment, prices, government decisions, and other social and economic activity.

Since the beginning of the project in 1973, the system dynamics group has devised most of these sectors and plans to spend the years 1975-78 improving and completing them, and validating the results by consulting real-life decision-makers and academic experts in each sector's field. Finally, after the sectors have coalesced into a workable model, they plan to use the model to analyze economic issues, outline policy alternatives, and try to improve theoretical understanding of the workings of the economy.

Among specific topics, the M.I.T. group hopes to develop policies for: the nature of economic growth, economic fluctuations, inflation, balance of payments, taxes, energy shortages, agriculture, and education.

Will It Work?

The aims of the model are sky-high, and Professor Forrester and his colleagues are used to being greeted with skepticism. The central question seems to be "How can a piece of hardware like a computer model such an irrational, complex, human-centered system as a nation's economy?" Economic theorists have never come close to any comprehensive overview, so why should system dynamics?

To such questions, the M.I.T. group responds with a recitation of the nature of their methodology. For one thing, they say, the method relies on representing the way decisions are made and variables interconnect in the real-life system itself. Thus, the National Model differs intrinsically from traditional economic models that make simplifying assumptions about "rational economic man" or "profit maximization." To illustrate the model's reality centeredness, all of its parameters represent operational real-life concepts. For instance, one parameter is "the number of month's worth of production held in inventory"; another is "the normal delivery delay for capital equipment."

Because of its reality-centeredness, system dynamics avoids several problems of econometric models. (The reader will pardon another insect-centered metaphor here.) If an economist were modeling an ant hill using present theory, he would be able to model either the input and output of the entire hill — a macroeconomic model — or the working of an individual ant — a microeconomic model. But it is the complex in-between structure that determines how well the ant hill functions. It is this structure that system dynamics aims to model and an ant-hill decisionmaker aims to affect. A system dynamicist would, no doubt, study the behavior of each type of ant, what he does, what he responds to and what responds to him. All these observations would then be incorporated into the model and the model tested against the behavior of the actual ant hill.

Economic models also aim at forecasting the future state of the economy as a basis for deciding what to do; in contrast, a system dynamics model would focus not on prediction but on developing guidelines to help actually *manage* what will happen. For instance, an economic model of the short-term business cycle would predict how random events might affect the next peak, but a system model could be used to design policies that would minimize the system's sensitivity to random disturbances.

The Human Factors

Any successful method for managing the economy must also take into account such intangibles as the mood of the people, and the M.I.T. System Dynamics Group claims to be able to incorporate such social variables into its model's structure. For example, including the effects on welfare and social security of attitudes toward public support of individuals. And it is possible to work with variables that do not have firm numbers attached, say the researchers. They can simply plug general estimates of the factor into their model and test how sensitive the model is to changes in the factor. If the outcome is insensitive, careful definition is not needed; if it is sensitive, decision-makers will have to be careful to include measures of the factor in their information to the model. But in either case, the dangerous route of ignoring the variable altogether is avoided.

The most convincing proof of the group's National Model will be its functioning in the cold, hard world; and the National Model with its various sectors, say its engineers, is continually subject to "validation." They plan to test how well the model describes actual behavior of the economy during the period 1850 to the present, also asking various members of the interested public and academia to rate the model's accuracy, and, of course, continually reviewing the model structure themselves. Any structure that does not behave realistically will be altered.

Overloading Society?

Finally, there is the question of the political effects of such a functioning model. As many observers have noted, technology tends to increase controversy, not decrease it. A model enabling exploration of all the policy alternatives may just be too much for politicians, business executives, or the man-on-the-street to handle.

Information overload will not be the case, say Professor Forrester and his group, because the computer is used in a different way in system dynamics than it is usually used. Instead of spewing out raw data to be coped with by a planner, such models offer rational, manageable frameworks that "protect" planners from information overload.

The Forrester group predicts that use of the functioning National Model will reveal to its users three types of policies:

— those which produce such unfavorable results as to be out of the question,
— those which produce such favorable results as to be obviously desirable, and
— those whose outcome can be favorable or unfavorable according to the assumptions fed into the system.

This last category, which the researchers contend will be relatively small, will be subject to debate and further investigation. But the large National Model and its streamlined, special-purpose versions will enable this debate to be informed, revealing ways to increase the desirability of the outcome by changing variables, approaches, and so on. And, of course, running policies through a computer is far, far less costly in financial and human terms than trying real-life social experiments — which begin with legislation and appropriations, take one or two decades to work into the nation's socio-economic structure, and sometimes produce surprising adverse results.

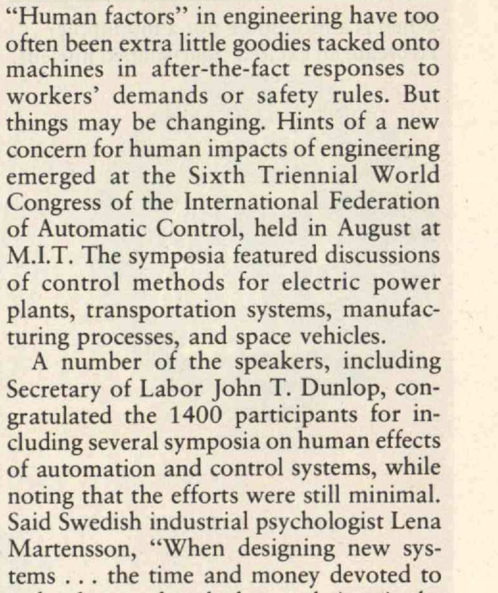
The National Model is a magnificent undertaking, say observers; whether it succeeds or fails, it will do so magnificently. — *D.M.*

AUTOMATION

Humane Engineering

"Human factors" in engineering have too often been extra little goodies tacked onto machines in after-the-fact responses to workers' demands or safety rules. But things may be changing. Hints of a new concern for human impacts of engineering emerged at the Sixth Triennial World Congress of the International Federation of Automatic Control, held in August at M.I.T. The symposia featured discussions of control methods for electric power plants, transportation systems, manufacturing processes, and space vehicles.

A number of the speakers, including Secretary of Labor John T. Dunlop, congratulated the 1400 participants for including several symposia on human effects of automation and control systems, while noting that the efforts were still minimal. Said Swedish industrial psychologist Lena Martensson, "When designing new systems . . . the time and money devoted to technology and to the human beings in the system are divided something like the



proportions of this congress: 6 per cent to the man and 94 per cent to technology."

"Many control engineers have a hidden dream: complete automation in which man's role is only that of consumer," said J. E. Rijnsdorp, Twente University of Technology, Netherlands. "However . . . even highly automated systems such as electric power networks need human beings for supervision, adjustment, maintenance, expansion, and improvement. Therefore one can draw the paradoxical conclusion that automated systems are still man/machine systems." He stressed that planning for human well-being is often quite economical.

Reducing humans to dial-watchers is not the way to go. "A high degree of automation tends to reduce supervisory work to 99 per cent boredom and 1 per cent terror, which is in conflict with human well-being," said Professor Rijnsdorp. The answer is to make jobs draw fully on workers' skills. The computer should not control processes, but should figure out alternative strategies for a human, who makes the final decision. Operators should have the power to turn alarm circuits on or off at will to control what alarms they respond to, and to change process procedures as new raw materials or processes appear.

A number of suggestions at the congress dealt with making machines better fit human needs: social scientists should be brought into the design process from the beginning, not merely called in as the need arises; mock-ups of any new control system should be built and workers given a chance to criticize them; samples of new machines should be tested by workers before the decision to buy is made.

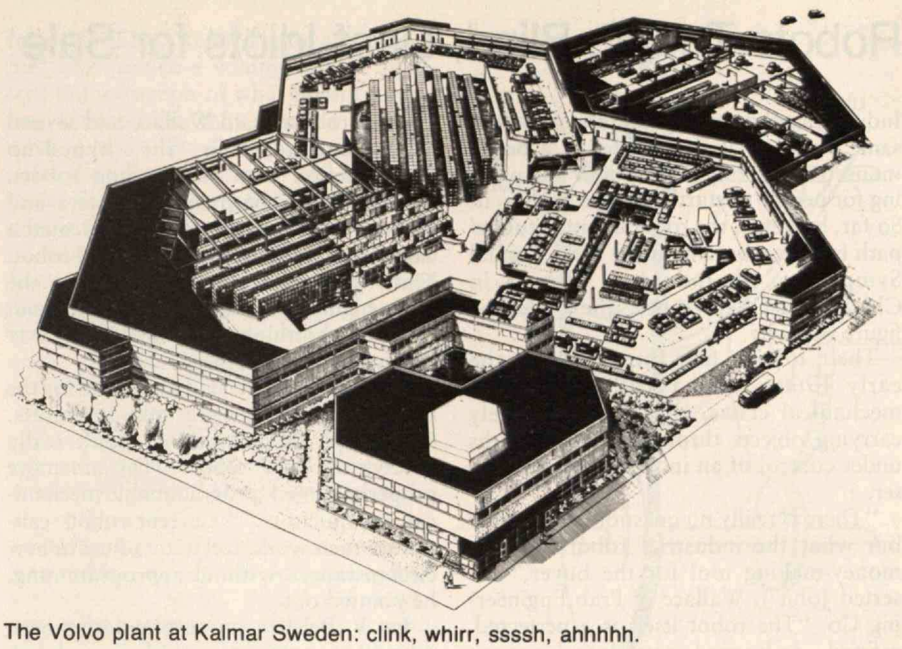
Any machine should give frequent feedback to the worker on his performance; should allow him to schedule his work as he sees fit; should let him see the final result of his work; and should give him responsibility for his output.

British psychologist Roger P. Maitland warned against automation which isolates man from his product. "[Automation] represents a qualitative mutation in the relationship between man and his tools," he said. The gap between the operator and the production process is widened; and the worker deals with an automated machine, rather than the process.

British engineer Howard H. Rosenbrock perhaps best summarized the arguments for humane automation.

"The computer and the human mind have quite different but complimentary abilities. The computer excels in analysis and numerical computation. The human mind excels in pattern recognition, the assessment of complicated situations, and the intuitive leap to new solutions.

"If these differing abilities can be combined, they amount to something much more powerful and effective." — *D.M.*



The Volvo plant at Kalmar Sweden: clink, whirr, ssssh, ahhhhh.

On the Line at Volvo

The new Volvo plant in Kalmar, Sweden, has become the most widely acclaimed example of how factories and control systems can be fitted for human habitation.

With an advanced computer control system, social amenities, and small-group manufacturing, the plant has become the subject of scrutiny by manufacturers seeking tips on making the assembly line more palatable.

At the control engineers' conference *(left)* the principal architect of the new plant described how he and his colleagues had put into successful practice many of the suggestions being contemplated by conferees. According to Walter Krieg, president of the Swiss corporation Digitron, although the new factory cost 10 per cent more than a conventional factory, production costs are believed to be lower and worker satisfaction higher. He said the plant has been in operation for only a year, so any conclusions are premature.

The Kalmar factory, now producing its full quota of 30,000 Volvos per day, was designed to answer some of the severe labor problems at other Volvo factories. The worst Volvo factory, at Göthenberg, was experiencing an average absenteeism of 20 per cent and a personnel turnover of 30 per cent annually in the late 1960s, a result of the numbing monotony of the assembly lines and the isolation of workers amidst clanking machinery. Experiments in making the work more attractive by rotating jobs, establishing work teams, and increasing job scope and responsibility were so successful that Volvo concentrated on worker satisfaction as well as efficiency in its new factory.

The huge new assembly plant is divided into numerous small work areas around the perimeter, each with its own entrance, dressing rooms, and lounges. Huge picture windows connect workers with the outside world; formerly many workers never saw the sun for weeks on end, as they went to work and came home in darkness. Gardens and brightly colored walls also add to the cheerful atmosphere.

Instead of a clanking conveyor belt, cars are transported by 18-foot-long "Robocarriers" — silent, computer-monitored, electrically driven pallets, on which each car is arranged for the workers' convenience. The pallets and other machinery are so quiet that normal conversation is easily heard, and many workers play taped music.

Although the computer keeps careful track of the cars in the plant and can control them, their progress is mostly controlled by the workers, who can position and move the pallets as they wish. Each 15-to-25-member team of workers can choose to perform traditional assembly line work, move from car to car, or move certain cars off the line for special work, or they can learn new jobs whenever they like. "Buffers" of six or so cars at each end of a work station allow the team to control its work pace, taking breaks when it is ahead of schedule, or laboring intensively to catch up.

Workers can query the computer in Swedish, Finnish, Yugoslav, or Turkish at any of 35 computer display screens to find out whatever they need to know about production schedules, quality problems or parts inventories. "I was astonished that everybody learned how to have discussions with the computer faster than they learned the assembly work," said Mr. Krieg.

While worker response to the plant has been generally positive, said Mr. Krieg, some groups prefer the old-time assembly line. Short-time workers and older workers have said they don't particularly want deep job involvement, preferring to invest their interest and energy in home, family, recreation or religion. — *D.M.*

Robots Today: Blind, Deaf Idiots for Sale

Industrial robot manufacturers are in the same situation as the builder of a better mousetrap, peering out the door and waiting for people to start beating a path to it. So far, however, the robot manufacturers' path is unbeaten, and at the Fifth Annual Symposium on Industrial Robots in Chicago last September, they tried to figure out why.

Their robots, first introduced in the early 1960s, are basically adaptable, mechanical claws, capable of precisely carrying objects through complex paths under control of an incorporated computer.

"There is really no question whatsoever but what the industrial robot . . . is a money-making tool for the buyer," asserted John J. Wallace of Prab Engineering Co. "The robot itself is a perfected, refined, de-bugged, tested and proven piece of automation. . . . They are so cost-effective," said Mr. Wallace, "that when we tell prospective customers what they can expect, it sort of spoils our credibility." Several studies presented at the conference bore him out, showing that industrial robots usually did the work of several workers, were mechanically reliable, easily programmed, and usually increased productivity. Then why, he asked, are there only about 3,400 robots in use world-wide today, and a straight-line prediction of 5,000 in 1984?

One problem, said Wallace and several other speakers, is the hyped-up science-fiction aura surrounding robots, encouraged by both manufacturers and the media. "We have somehow created a 'superman' image for the industrial robot. This, of course, is not true of even the most highly developed robot," he said. "People who think of robots in that way are quickly disappointed."

Some participants laid the blame for the idealized image on the manufacturers. Said one, "These machines don't really deserve the title 'robot.' They are more properly termed 'programmable mechanical manipulators.' " Current robots cannot see their work, feel it, or adjust to new circumstances without reprogramming, he pointed out.

Jay V. Belcher, an automation expert, related his experience with a study on robot feasibility in manufacturing: "When managers or supervisors would hear that I was studying their factory for industrial robot uses, they would invariably take me over to the most difficult job in the place, and tell me 'This is where I need a robot.' " Mr. Belcher and others stressed that robots are generally not best suited to new jobs, but to jobs that are already being done.

Candidate jobs for robotization are those which:

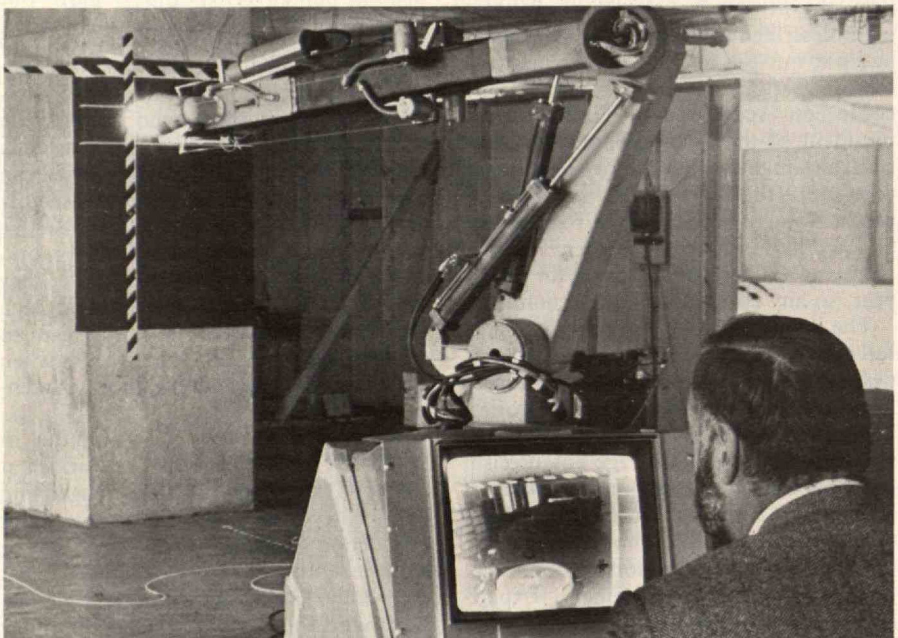
— are too dirty, dangerous and boring for humans, and/or

— change so frequently that hard-wired automation would become out-moded.

Participants in the conference told how robots had successfully performed machining, welding, molding, furniture refinishing and spray painting. The common denominator of all the jobs seemed to be that the piece to be handled was of moderate weight and the path through which it was carried for processing, while fairly complex, did not require an extreme amount of precision or adjustment to new circumstances, out-of-place parts, etc.

In addition to the unfortunate image, manufacturers bemoaned the general inertia of industry: managers fear the risk involved; worry over the lack of in-house capability to maintain a robot or the necessity for hiring new experts; worry over a robot's effects on labor-management relations; and wonder whether present machines and procedures will be badly disrupted by robot introduction.

Although the number of future developments discussed by academics at the meeting — robot vision, robot touch, two-handedness — gave the conferees a warm feeling about the future there is still the cold reality of selling robots now. As Mr. Belcher said, "My problem is not in getting more sophisticated equipment, but in effectively using what is already available." — *D.M.*



"Maybe not a throwaway, but perhaps a blowaway," is how developers describe this robot teleoperator system for obtaining samples of experimental explosives from processing apparatus. The robot was developed by Illinois Institute of Technology Research Institute for the U.S. Army. Its task typifies the boring yet dangerous jobs at which robots excel. (Photo courtesy of I.I.T. Research Institute)

How to Buy a Robot

Manufacturers at the Symposium on Industrial Robots (*above*) gave a number of tips to would-be buyers of their product.

First of all, they said, consider for robotization hot, dirty, repetitive, dangerous, or tiring jobs that are simply beneath human beings. Robots now on the market can coordinate with other machines or moving assembly lines, can stack or unstack objects, and can follow complicated paths quite easily. According to robot users at the conference, however, present robots may have trouble with large objects — over several hundred pounds — and cannot precisely handle tiny objects requiring great precision or adaptability. For instance, a robot cannot assemble a carburetor.

Any company buying a robot should have the need for more than one to justify their trouble. Joseph Engleberger, President of Unimation, Inc., the world's largest producer of industrial robots, declared, "We don't sell one robot to any company that can't use five."

Make sure the company management is really committed to using the robot. "I've seen many installations where the robot is half-installed, the one man responsible for it changes jobs, and the robot consequently sits in the corner gathering dust,"

said Jay V. Belcher.

Begin talks with both labor and management very early about the possibility of robot introduction, making sure each understands the benefits and how they will share them. Include not only the financial and productivity benefits, but the safety and health benefits of the robot.

Lay no one off because of the robot, but retrain and reassign early those replaced by the machine.

Invite the press to demonstrations of the new robot, showing both how the process was carried out before, and how it is carried out with the robot.

Hire or train in-house technicians to repair and maintain the robot so a malfunctioning unit can be repaired in minutes with minimal help from the factory.

Finally, consider the robot as a long-term device which can be reprogrammed for new jobs. Frank A. DiPietro, a manager at General Motors, described the remarkable durability record of 26 robots used to weld Chevrolet Vega auto bodies at G.M.'s assembly plant at Lordstown, Ohio. Since 1970 each of the robots has undergone 50,000 hours of use, with overhauls at 20,000 hours, and the robots have made 625 million spot welds on 1.6 million auto bodies.

Said Mr. Engleberger, Unimation's robots have proved so durable that the company is haunted by a number of early robots which it agreed to sell and service cheaply to get the product rolling. The robots have lasted so well that Unimation is in a position of supplying the hard-to-fabricate parts at a loss, because users refuse to buy newer models. — *D.M.*

ENERGY

The Stretch for New Energy

Clearly man's dependence on fossil fuels and the ways he has heretofore chosen to treat and use them are more than an accident; these are indeed the resources of choice, hard to improve upon and harder still to replace. Despite a prodigious 1,500-page volume of technical papers produced by the Intersociety Energy Conversion Engineering Conference (mechanical, chemical, electrical, nuclear, automotive, and aeronautical) held this summer at the University of Delaware, workers in the coming decade can point more to unsolved problems than to proved innovations.

1.7 Billion Tons of Coal for Cars

After an intensive study for the Environmental Protection Agency, a team at Stanford Research Institute concludes that by the year 2000 four million barrels of crude oil and perhaps eight million barrels of methanol might be produced daily from coal, and two million barrels of oil from oil shale. Refined into automotive fuel, this immense volume would represent but a fraction of what thirsty American automobiles may need a quarter-century hence. But that output would require the full production of 352 coal strip mines (each producing five million tons of coal a year) and over a billion tons of oil-bearing shale annually. There would have to be 40 large coal liquefaction plants, 20 shale processing plants, and 80 large refineries making methanol from coal — a total capital investment of just under $100 billion (1973 dollars).

If these numbers strain credibility, realize that some of the automobiles in this scenario of the future will be manufactured within the next decade, and a few of them already exist.

The resources of western coal and shale are ample; constraints will come from shortages of capital, skilled manpower, water, and from environmental acceptability, thinks Michael H. Farmer of Exxon Research and Engineering Co.

What about a hydrogen-powered automobile? Surveying that innovation, William J. D. Escher, an engineering consultant, finds himself uncertain; even after 15 different research groups have modified at least 42 automobile engines to run on hydrogen, we still lack "a comprehensive and coherent basis for evaluating the hydrogen engine," he says. Another alternative added during the Intersociety Energy Conference: three engineers from the Jet Propulsion Laboratory reported that small amounts of hydrogen mixed into the gasoline burned in an automobile engine resulted in better mileage and lower emissions.

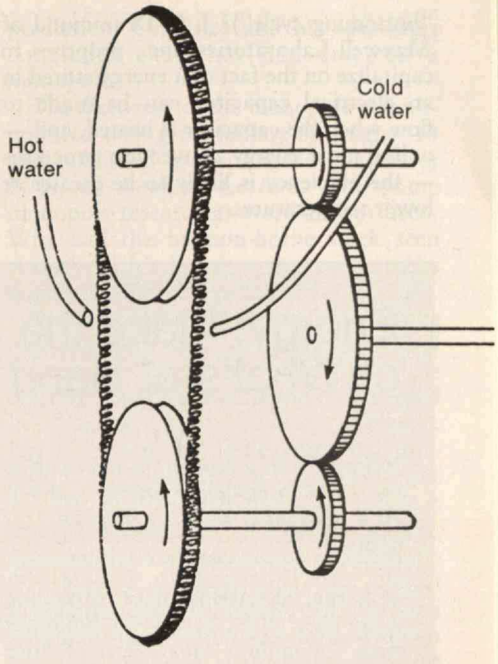
Adding "Topping" and "Bottoming"

For those who seek a radically new energy source, or even sharply more efficient use of those we have, materials are a critical and highly technical bottleneck.

The goal of a major federal program is to achieve a 100-fold reduction in the cost of photovoltaics — the materials carried on spacecraft that convert solar energy directly into electricity. Leonard M. Magid of E.R.D.A.'s Solar Energy Division admits that without success in that materials research program, these remarkable devices remain prohibitively expensive for general use.

The success of immense flywheels for storing energy also depends on materials from which to build them. The stored energy in a flywheel is proportional to the square of its speed, and the strength of fiber-reinforced composites now limits the speed and weight of flywheels. This is "the most obvious area for improvement," says R. L. Fullman of the General Electric Research and Development Center.

Remember the old-fashioned radio tube, in which electrons were "boiled off" a hot cathode and drawn to the anode? It was a primitive energy converter, using heat to create an electric current. Now the



A nitinol (nickel-titanium) helix strung over two pulleys is a primitive motor. Hot water on the nitinol causes it to expand, and cold water causes it to contract; so the pulleys turn. A helix weighing 17 grams has developed 2.2 watts of shaft output, says A. D. Johnson of the University of California's Lawrence Berkeley Laboratory.

same process figures in plans for increasing the efficiency of electrical generating plants. If more efficient and more prolific thermionic emitters can be found, they can be installed in boilers raising steam for electric turbines. The converters will tap the highest-temperature heat before it enters the boiler to create supplementary power, and the addition of such a "topping cycle" (using the "top" of the combustion heat) might increase total plant efficiency to above 50 per cent (today's best steam plants operate at just over 40 per cent efficiency). Two centers of thermionic research — Rasor Associates, Inc., of Sunnyvale, Calif., and Thermo Electron Corp. of Waltham, Mass. — are working on routes to the needed new materials.

The gas turbine is an alternative "topping" cycle with its own strong advocates, including a team at United Technologies Research Center in East Hartford, Conn. The plan is to gasify coal and burn it at high temperatures in a gas turbine. If the turbine can be operated at temperatures as high as 3100°F. (high-temperature materials are a key issue) it would generate considerable power and still produce exhaust gas hot enough to raise steam for a conventional steam turbine. Such "combined-cycle" systems might reach 55 per cent efficiency.

Can a suitable material make possible dielectric power conversion, using waste heat exhausted from a steam turbine (a

"bottoming cycle")? J. E. Drummond of Maxwell Laboratories, Inc., proposes to capitalize on the fact that energy stored in an electrical capacitor can be made to flow when the capacitor is heated, and — unlike most energy conversion processes — the efficiency is likely to be greater at lower temperatures.

Another materials-limited concept, from Michael S. S. Hsu, Walter E. Morrow, and John B. Goodenough of M.I.T.'s Lincoln Laboratory: separate water into its constituent oxygen and hydrogen at high temperatures (1200° to 1500° K.) and let them recombine in a fuel cell at more moderate temperature (530°K.); the recombination releases electrical energy, and the Lincoln workers calculate an efficiency "exceeding 50 per cent." The medium-temperature fuel cell is a materials problem.

Nitinol and the Heat-Powered Auto

If some of these schemes for raising energy sound exotic, consider such devices as the following:

— In a "lead oxide" fuel cell, under study at Stanford Research Institute, molten lead and oxygen react to produce lead oxide and electricity, then the lead oxide is reduced with coal to lead and oxygen. The system would operate at 500° to 800°C., and overall efficiency may be more than 40 per cent.

— To store energy in a wind energy system, use surplus energy obtained when the wind is strong to separate water into oxygen and hydrogen by electrolysis. The two elements can later be recombined in a fuel cell to produce electricity, or in a burner to produce heat.

— Use an "annual cycle" energy system for heating and cooling a home. In the winter the home is warmed with heat obtained by cooling (and eventually freezing) water in a large "ice bin" under the house; in the summer the house is cooled with the ice, which gradually melts. In areas where electricity costs 2.5 to 3.5 cents per kilowatt-hour, says H. C. Fischer, a consultant to the Energy Division at Oak Ridge National Laboratory, this system would be competitive in cost with electric resistance heating and room-size air conditioners.

— Nitinol is a unique nickel-titanium alloy whose mechanical and electrical properties change drastically during a crystalline phase change at modest temperatures. The result is a memory for shape: if deformed while cool, nitinol will return to its undeformed shape when warmed. Alternately heating and cooling, it causes motion — a conversion of heat to mechanical energy.

— Instead of an electric automobile with its motor and battery, how about a heat automobile with a thermal engine and heat storage system? Jack R. Kettler of the Aerospace Corp. suggests a Rankine cycle engine with an organic (low-temperature) working fluid and heat storage in an inorganic material with an appropriate transition from liquid to solid phase. Such a thermal vehicle would "easily provide greater driving range than a lead-acid-battery electric vehicle" of equivalent weight, says Mr. Kettler.

— Workers in the College of Engineering at the University of Illinois are studying an "electrofluidic" generator in which droplets or particles charged by a corona discharge are carried across an electric field to a charge collector, where they deliver their charges at a greatly increased voltage.

— From the U.K. Atomic Energy Research Establishment comes a plan for

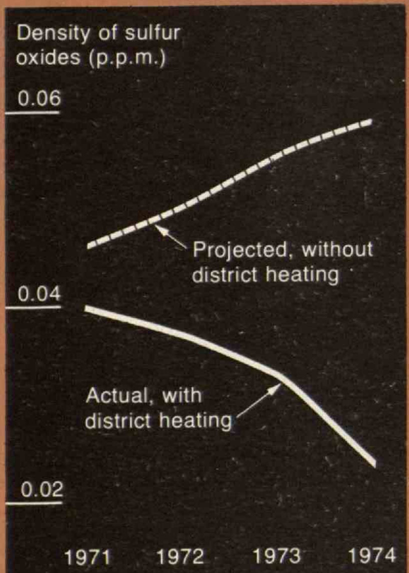
Energy: Make the Most of What's at Hand

Jottings from a reporter's notebook at the 1975 Intersociety Energy Conversion Engineering Conference (see above):

— A central heating plant, providing water at 428°F., serves 60 buildings with 7.6 million square feet of floor space in 0.6 square miles near the city center of Sapporo, Japan. Before the system began operating in 1971, sulfur dioxide concentrations in the air over Sapporo were increasing at the rate of 9.4 per cent a year; since then, the SO_2 concentration has decreased each year from the previous year by 6.6 per cent, 11.9 per cent, and 27 per cent, said William Diskant, Executive Vice President of American Hydrotherm Corp. of New York City. Now 32 other similar district heating systems are in operation or being planned in Japan; one burns refuse as a fuel source.

— Over 8,000 farm households in Taiwan make and use their own "marsh gas" for cooking and — in a few cases — for generating electricity. "Marsh gas" is methane, and on Taiwan farms it is generated by the decay of waste products from hogs. China's Joint Committee on Rural Reconstruction, said Eric K. Y. Kang of the Taiwan Energy Policy Committee, will provide methane generators to pig farmers who have 25 or more animals; each hog's manure yields 500 to 700 liters of "marsh gas" daily. The fermentation reaction begins within about 24 hours after the manure enters the generator, and methane pressure pushes the manure through the generator so that it is ready to remove for use as fertilizer when the process is exhausted ten to twelve days later. Mr. Kang admitted that the cost of "marsh gas" from hog waste with this technology "seems to be higher" than the cost of energy from other sources, but when pollution control and waste management are considered, "marsh gas begins to be economically attractive," he said.

— As late as 1880 wood was the largest source of energy in the U.S. John A. Alich, Jr., and R. E. Inman of Stanford Research Institute think we can never return to that day of renewable fuels. They calculate that a 1,000-megawatt electric plant operating at an 80 per cent load factor would require the biomass from a land area of about 250 square miles. Some 700 million gallons of water would be needed daily on that area, either as rain or irrigation. The power produced would be more expensive — by two or three mills per kilowatt hour — than that from today's efficient coal-fired plants. If the biomass were used to produce synthetic natural gas, the gas would cost at least $1 per million B.t.u. more than the cost now forecast for gas to be made from coal. — *J.M.*



The concentration of SO_2 in the atmosphere of downtown Sapporo, Japan, was rising 9.4 per cent a year when an oil- and coal-fired central plant (300-foot stack with cyclone dust collectors) supplying water at 428° F. began heating and cooling 22 buildings in a 0.6-square-mile area. By 1974 60 buildings were on the system, and SO_2 was sharply down.

converting heat from the gradual decay of a radioisotope into alternating electrical current. The heat operates an oscillating diaphragm to move a magnet through a magnetic field. A 52-watt generator powered by the strontium-90 is now proposed as an underwater electric plant. — *J. M.*

PHYSICS

How the Monopole (Maybe) Was Found

The discovery of one of the most sought-after particles in modern physics, the magnetic monopole, was announced last August by a team of physicists from Berkeley and the University of Houston. The team, led by P. Buford Price of Berkeley, claimed to have found the track of a monopole in a cosmic ray detector which they had flown on a stratospheric balloon over Iowa in 1973. The rug was pulled out from under the discovery a few weeks later however, when Luis Alvarez, another Berkeley physicist on the trail of the monopole, announced that the discovery had been partly based on a mistaken assumption about the detector size.

Magnetic monopoles are particles which act as magnets with only one pole. Because magnetic poles are analagous in theory to electrical charge, the monopole's apparent absence from nature disturbs what would otherwise be a symmetrical relationship between electricity and magnetism.

In 1931, the famous British physicist, P. A. M. Dirac, predicted the existence of monopoles and showed that their discovery would explain the quantization of electric charge. The 35-year chase succeeding this prediction has defined magnetic monopoles by their absence: assuming they exist, they must be rare (because none have yet been captured in an experiment); and they must be massive, requiring much energy (because none have yet been created in a particle accelerator, the way the j-particle was created last year).

Monopoles have eluded creation on earth, so physicists look to the skies. If monopoles exist, they would have been created in the primordial explosion that began the universe. Between then and now, those monopoles could have been accelerated around the universe by the weak magnetic fields that permeate space, and could have attained energies on the order of 10^{20}Gev. Monopoles should therefore be a part of the cosmic-ray spectrum raining upon the earth. Any monopole striking the earth, after losing its energy, would eventually attach to iron or any other ferromagnetic material. Although it should be possible to magnetically pump the monopoles out of these materials and accelerate them through particle detectors, experiments with rocks and iron-rich ocean sediment have been fruitless. In 1971, Dr. Alvarez failed to find magnetic monopoles in lunar material collected by Apollo 11.

Most of the attempts to detect monopoles are based on measuring the ionizing effects of the monopole on materials it passes through. Because electrically charged particles produce more complex tracks, detecting the passage of an actual monopole against the constant flux of more conventional particles depends on recognizing and distinguishing their different signatures.

The Berkeley-Houston experiment led by Dr. Price was part of a series of balloon flights to study ultraheavy cosmic rays: nuclei with atomic numbers over 60. These particles, although rare in the cosmic flux, provide information about nucleosynthesis in stars. The balloon carried a 20-square-meter detector stack which was composed of three elements: a Cerenkov radiator and film combination, a layer of G-5 emulsion, and 32 Lexan (plastic) sheets. Each of the detector types contributed independently to the finding that a magnetic monopole had passed through the stack.

The Cerenkov radiator is a slab of dielectric material that emits a flash of light when a particle exceeding the speed of light in the material passes through. The flash spots the film, marking the passage of the particle. No flash was recorded where the alleged monopole entered the stack, indicating that the particle's velocity was less than 0.68c.

Charged particles that pass through the emulsion layer leave tracks which can be analyzed to diagnose their charge and speed. The supposed monopole tracks were first discovered while searching that layer with a stereomicroscope. The track structure suggested to Dr. Price's team that the track had been made by either a nucleus with a charge (Z) of 80 or a monopole — both with a velocity of 0.5c, in agreement with the Cerenkov radiator.

Particles passing through the plastic Lexan sheets break polymeric chains. The sheets, soaked for 30 hours in sodium hydroxide, show particle tracks as cone-like pits in the plastic. The depth of the pits indicates the ionization rate, used to measure the charge and velocity of the particle. The particle in question had gone through the entire stack at a uniform ionization rate — a characteristic of monopoles. The result was consistent with two interpretations: a nucleus with Z larger than 125 and velocity of 0.92c, or a magnetic monopole whose magnetic charge was 137 times as strong as the electric charge on an electron of undetermined velocity.

The former hypothesis was in disagreement with the data that showed the particle to be moving more slowly. In addition, no particle with Z greater than 96 has previously been found in cosmic rays. The charge was in agreement with Dirac's prediction. Dr. Price and his associates concluded that they had detected a monopole.

The discovery of the monopole was announced with great fanfare on August 14 and published in the August 25 issue of *Physical Review Letters,* but some monopole researchers were unconvinced. Why had the balloon-borne stack seen something in a few days that moon rocks hadn't in 500 million years?

Working independently on an alternate explanation, Dr. Alvarez, a Nobel laureate, contacted the assemblers of the detector stack and found that it contained less than the reported 32 layers of plastic. Dr. Price and his colleagues had mistakenly assumed that this detector stack was identical to ones flown on previous flights. In some eyes, this discovery damaged the claim of discovering a monopole. Dr. Alvarez concluded that the alleged monopole track had been made by a platinum nucleus that had broken down into osmium and then tantalum as it passed through the stack — an interesting occurrence, but not revolutionary.

Dr. Price maintained that the data still pointed toward the monopole. He is preparing to analyze the last four Lexan sheets, which had been on the top and bottom of the stack. The analysis of these sheets, he claims, will clear up several areas of dispute, including the velocity of the particle, and resolve the issue of the monopole. — *Dennis Overbye*

A Nuclear Molecule

A carbon-carbon nucleus — a kind of "Siamese twin" which its producers call a "nuclear molecule" — has been created by a team of scientists from M.I.T., the Argonne National Laboratory, and the Niels Bohr Institute. It is in fact an excited cigar-shaped magnesium nucleus which is stable for a brief instant (10^{-21} seconds) in a condition that is somewhere between complete independence and complete fusion. It then decays into a sodium nucleus and a single surplus proton.

Professor Eric R. Cosman of M.I.T., one of eight authors who reported the new nuclear form in *Physical Review Letters,* says it is "a fascinating object in itself. And by understanding its unusual structure and formation," he says, "we may be able to predict what will happen in other nuclear fusion reactions." Such reactions, uniting heavier elements into long-lived or even stable super-heavy nuclei, have been predicted; if they can in fact be made, they would be extremely compact sources of energy for nuclear reactors.

The carbon-carbon nucleus was created by bombarding stationary carbon nuclei with target carbon nuclei at certain "resonant" energies. At other energies the nuclei fail to interact or, at high energies, merge completely. — *J.M.*

Alternative Energy: Living On Our Interest

Special Report
by
Sara Jane Neustadtl

R. Buckminster Fuller hovered over the microphone. "When steamships were introduced they were slow. If a storm blew one off course it would likely run out of fuel. Sometimes when it finally pulled into port they would have burned all their furniture, and sometimes the ship would be stripped — decks, furniture, whatever would burn — all the way down to the water line.

"The steamships that also had sails were better off. They could move on the free wind rather than burn themselves up. When we use all our coal, oil, when we start to use nuclear power — we're burning our own ship.

"Alternative energy resources are of immeasurable importance."

The audience — over 300 engineering students, 30 professors, and a sprinkling of working engineers — made no response. They already knew the importance of energy resource alternatives, and had been laboring beneath the Albuquerque sun for over a week to make the same point. Each member of the 40 competing teams from 33 universities and one high school, in the U.S., Canada, and England had designed and executed systems for homeowners that would run on "free" energy from wind, sun, and waves.

The competition was the third organized by S.C.O.R.E. (Student Competitions On Relevant Engineering). An offshoot of the 1970 Clean Air Car Race, S.C.O.R.E. is a student-run organization that provides graduate and undergraduate engineers with a framework in which to develop their own ideas on engineering problems of social import. This year's competition was called E.R.A., Energy Resource Alternatives, and culminated in a week of testing and judging at Sandia Laboratories in Albuquerque, New Mexico.

Charge it to Mother Nature

Dr. Fuller warmed to his subject. Mother nature provides crude oil for free, he said, but if she were to charge us as manufacturers do, counting the cost of sunlight to grow the plants, the wind to blow over them, the bacteria to decompose them, the heat and pressure to turn them to oil, each gallon would cost a million dollars.

"We're living on capital," he continued. "Wind and sun are 'energy interest.' We've got to find ways for us all to live on our interest."

The competition recognized that the cost of making energy interest into usable power would not be low. One of its judging guidelines considered the cost, and thus the marketability, of the finished product. The competitors found that if they came up with a system that would pay for itself in, say, ten years, they were doing well.

A cost-conscious team from the University of California at Berkeley designed a solar collector to take advantage of cheap and available materials, without sacrificing efficiency, and was awarded second prize for its effort. The three-person team made a flat plate collector of aluminum and heat-resistant black paint, all purchased at the hardware store. To prevent long-wave radiation from escaping from the collector, they covered it with tubular glass of the sort used for fluorescent lighting: cheap, easy to replace, and about a tenth the cost of regular glass. The heat was stored in melted paraffin, and the entire system cost about $1,200.

Three days into the competition, they plugged in a faulty extension cord brought from Berkeley and were forced to rework the entire system. Team member Tony Wexler shrugged off the mishap. "The real thing was the learning experience," he muttered as he made his repairs.

A senior in physics, Wexler had been interested in solar energy long before the competition was announced. The entry his team presented had been in the works for 18 months, and that was a six-month head-start on most of the other teams. Wexler saw their entry as the beginning of a major alternative energy effort at Berkeley, and as a direction for his own future work. "I want to build a solar refrigerator next," he said.

Another entrant well aware of the cost of alternative energy systems was Mark Bohon, a one-man team from the University of Oklahoma. "Three years ago I wanted to build a house that could cut itself off from public energy completely," he said. He had immediately realized that "solar energy won't be cheap. People won't want to pay for it until it's too late."

Taking the E.R.A. guideline of a "complete" home system literally, he designed a system that could provide electricity, hot water, heat, air conditioning, and power for a solar car. Designed and executed singlehandedly — "That way nobody could give me hassles," he explained — his system included a parabolic reflector made of paper-thin silvered glass, a photocell tracker to aim the reflector at the traveling sun, and a pressurizer to contain super-heated steam at high temperatures.

But Will It Run?

"I want to come to the banquet and clap for everybody that wins," Tony Wexler had said. But Dr. Fuller continued:

"Human beings were designed to make mistakes. They learn to think for themselves by going about things by trial and error. From time to time human beings can pull things together — that's learning. Making mistakes is part of the human condition."

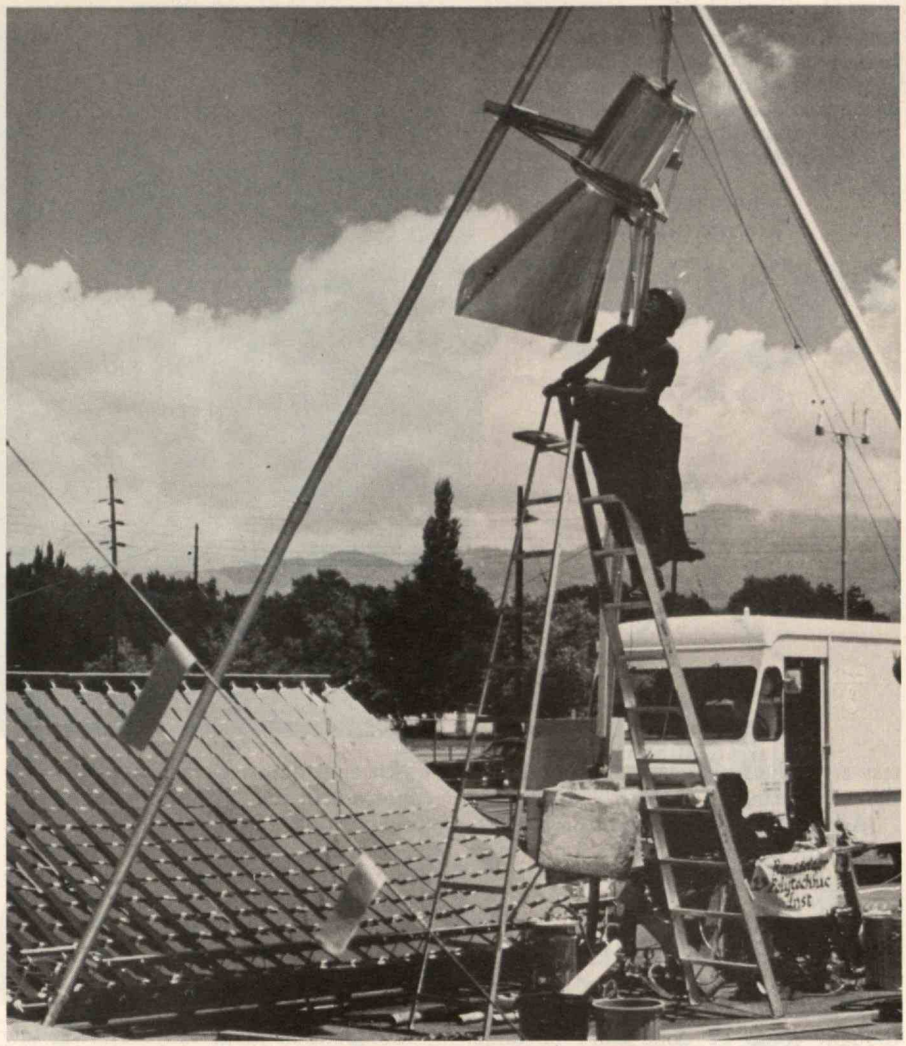
A few eyes turned to Professor F. O. Smetana of North Carolina State University — faculty adviser to the team whose mistake had been largest and most obvious.

North Carolina had built a 30-foot tower of pipe and attached six huge, white fiberglass cones at various heights. They were trying for an improvement on the Savonius rotor, but they wound up with a disaster. On the first day of testing, a desert thunderstorm blew their rotor apart.

Professor Smetana was upset. The 10-foot cones would have to be rebuilt, requiring "another three weeks of hell," he said, "and the system had never been designed to withstand 65 m.p.h. winds."

But the rotor had crashed its first time up in Raleigh, too, and hadn't tested well in its short three hours of working life. "We're showing it at the state fair in October, though," he added.

Bill Rogers of Rensselaer Polytechnic Institute checks the flash-boiler suspended at the focus point of an array of 350 mirrors. The steam from the boiler could be used to provide heat, hot water, and run a steam turbine to make electricity for a home. Below, team members from the Illinois Institute of Technology show their prize-winning, low cost, flat plate solar collectors.



There were other examples of learning through mistakes. An entrant from the University of Houston proved his electrical engineering ability by designing and building an AC-DC converter to run off a windmill he also designed. But his aeronautical and astronautical skills were a problem. His windmill spun backwards. The University of Florida team was forced to make their windmill a ground display for lack of a standing tower: they had cut the attachment pipe at the top of their 28-foot tower five inches too short. Team member Joe Hinson was philosophical — the learning experience was for him as valuable as any prize.

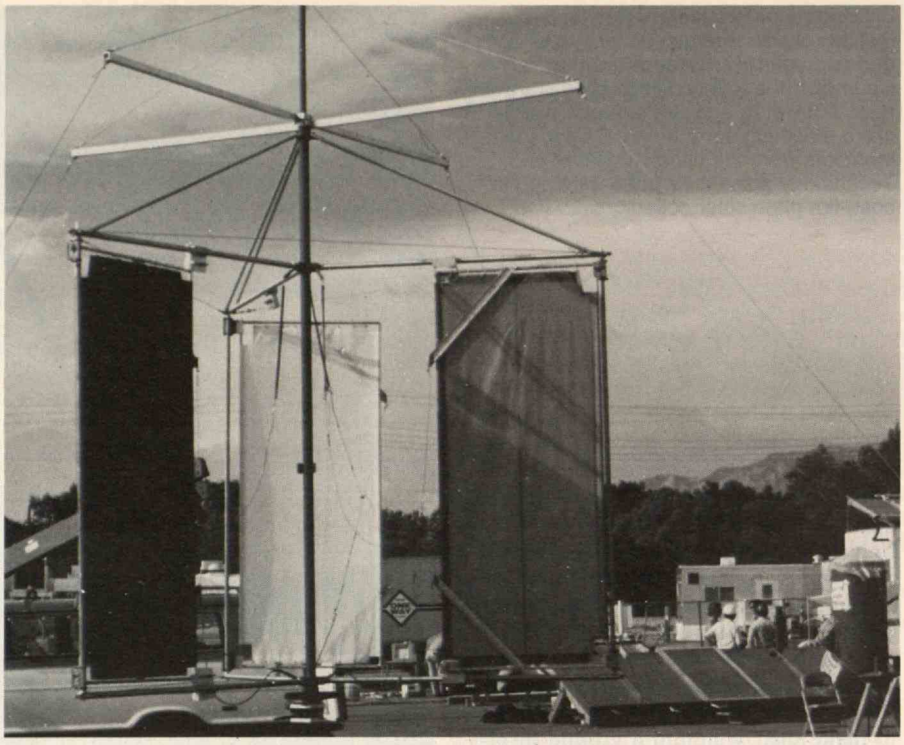
"Until you've had a chance to design things yourself, you just don't know. A computer can't tell you everything," he said.

Less visible than the mistakes were the systems that worked well, such as the University of New Mexico's solar system which could provide any mobile home with heat and hot water. The technology is not new, but this project is the first to integrate an alternative energy source into a mobile home system and prove it can be done.

One dark horse was an entry by a second University of Oklahoma team, which had built an anaerobic decay chamber to provide power for an entire farm in Oklahoma. Since the project was already in use, and since the bacteria that live in the decay chamber would have died in transit, the system was left behind. Oklahoma's entry is another example of the more practical aspects of the competition. Orders for similar systems have been coming in from other farms in the University of Oklahoma area.

The best entry according to the judges, who awarded it the grand prize, was a modest offering by students from the Illinois Institute of Technology. Their solar collectors were ceiling panels converted to flat plate collectors by black paint and plastic coverings. The collectors heated water which was stored in a unique compartment which stratified the temperatures of the water, keeping the hot water hot. Conspicuous only in the lack of furious last-minute activity around their

"The Flapper," built by students from the University of Oakland, has three sail-like blades that swing back and forth as the windmill spins on its axis, enabling the windmill to operate under any direction of wind. At its base, the windmill is connected to a D.C. generator.



test area, their professional attitude and thorough planning paid off.

(Asked what about their project deserved the grand award, an I.I.T. team member said: "It worked.")

Simplify, Simplify

"Every time you and I make an experiment we always learn more. We can't learn less. We may learn that what we thought could be done can't be done. Nothing could be more important than that," Bucky Fuller continued.

On just about any day of the five-day competition the engineers of Sandia Laboratories, most of them well past their student days, could be found examining the entry offered by Bill Rogers of Rensselaer Polytechnic Institute. Their fascination stemmed from a problem at Sandia, which Rogers may have solved. He built an array of 350 mirrors that reflect sunlight in fine focus into a flash boiler suspended over them. "Innovative," according to Lloyd Herwig, head of solar research at E.R.D.A. and a competition judge. "Impressive," according to the Sandia engineers, who had just received a $12 million contract to build a full-scale version of the same device. Rogers focused his mirrors with a mechanical system, much simpler than the computer complex Sandia was struggling with. This simple system, small enough to be crowded into a Volkswagen van with four people and a dog on the trip from New York, hinted broadly to Sandia that their huge and expensive computer tracking system would better be scrapped in favor of the mechanical method.

Beyond Rogers' entry, true innovation was scarce, as the teams themselves were quick to point out. Herman Drees of M.I.T. had built a Darreius rotor — a device which, according to Oregon State, had been conceived in the seventeenth century by Robert Hook. In turn, M.I.T. made sure the Oakland University team knew that their vertical sail (a red, white, and blue windmill they call "the flapper") had been used in China since 500 B.C. And the University of Wisconsin at Milwaukee happily rebuilt a farm windmill that had been manufactured in the early 1930s.

Competition judge Lloyd Herwig saw few innovations, but not for lack of the inventive spirit. About a quarter of the teams had projects which he considered copies of actual systems now in use; about half took old ideas and found new methods or materials to build them — just enough to call the systems their own, Herwig said. Only the remaining fourth represented ideas that had never before reached the stage of experimental working models, and "something could come of these," Dr. Herwig said.

"But this competition is not an exercise in invention," he added. "These students will be the backbone of new engineers in energy, and they have all learned that systems don't integrate as easily as theories. E.R.A. is a beautiful educational tool."

But Dr. Herwig was not so pleased with the scoring system, an opinion shared by many of the students. Points were awarded on the bases of design simplicity, safety, multiplicity of energy outputs, environmental impact, cost, efficiency, geographic versatility, and performance of prototype hardware. Dr. Herwig took issue with the relatively high weighting of environmental impact ("How much damage can a solar collector do anyway?") which gave unfair advantage to the teams experimenting with sun power, and the under-rating of cost and marketability. In any case, rating the entries was tough. Some teams relied on junkyards and donations for equipment; their entries were, as Dr. Herwig put it, "hassled together," and thus could never be rebuilt in exactly the same way. Other teams with more money, or better connections, obtained the newest and best equipment, and of course got more verifiable results.

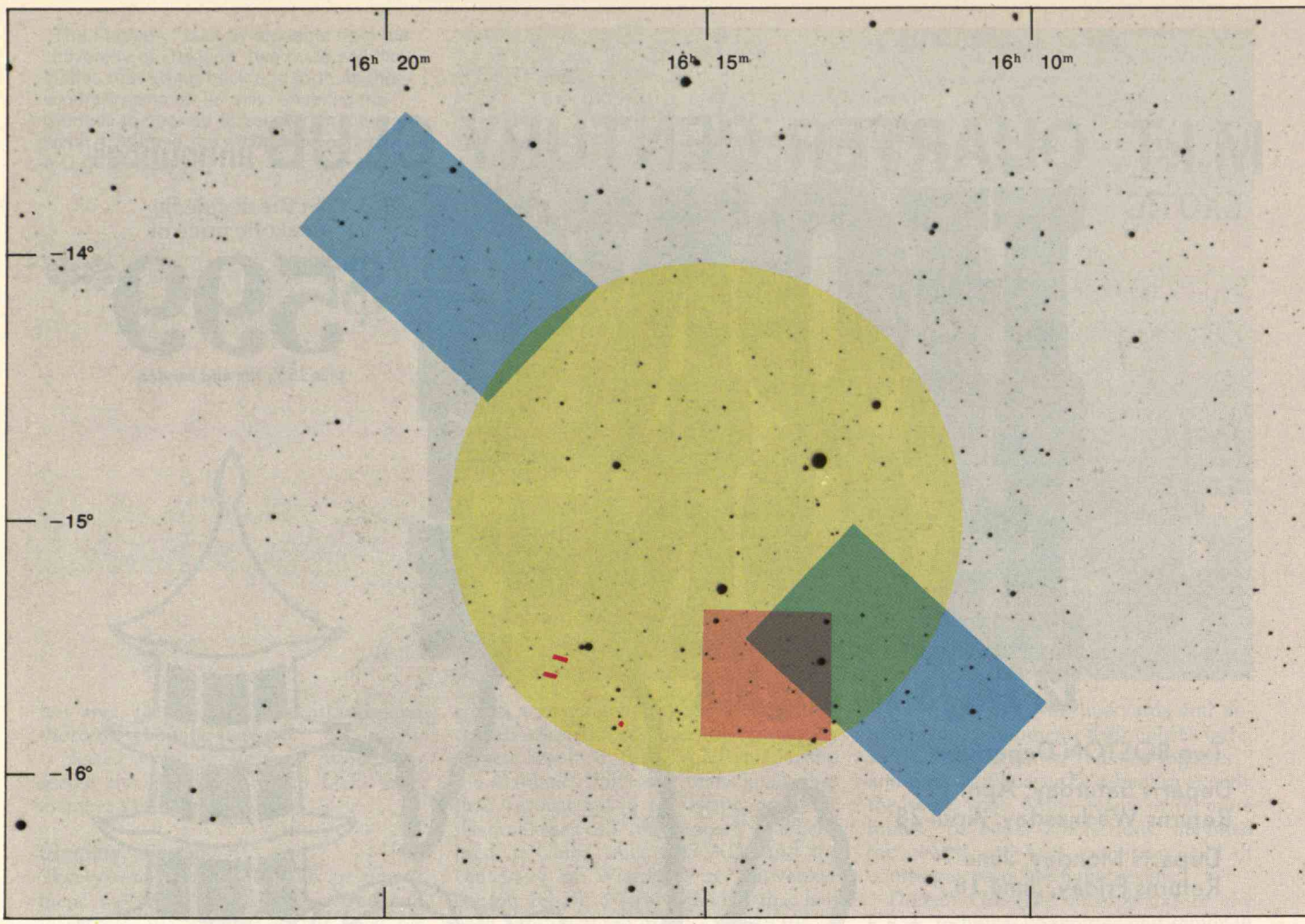
Doreen Osowski, chairperson of the E.R.A. technical committee and senior in nuclear engineering at the University of Wisconsin, used a scoring method that increases student involvement in S.C.O.R.E. competitions. Called the Student Innovation Multiplier, it gives students a chance to judge one another, and with the empathy that developed among the competitors, these scores were uniformly high.

Each team seemed to understand the others' problems, and cooperation was common. Teams shared equipment and advice. R.P.I. at one point was cycling its sun-heated hot water to Drexel University, which was demonstrating an industrial water reclamation device. Drexel in turn sent the slightly cooler water to Tufts University to run a "solar" air conditioner.

All This and Energy, Too

Dr. Fuller pulled into the home stretch.

"I couldn't be more excited than I am by what you have undertaken to do, and by what you're learning to do. Colleges have finally grown wise enough to accredit what you're doing, and society is finally beginning to see how terribly significant it is. You're discovering how to really do the things that will support life, you're looking out for the individual family, and you're learning how to get along on our energy income."


16h 20m
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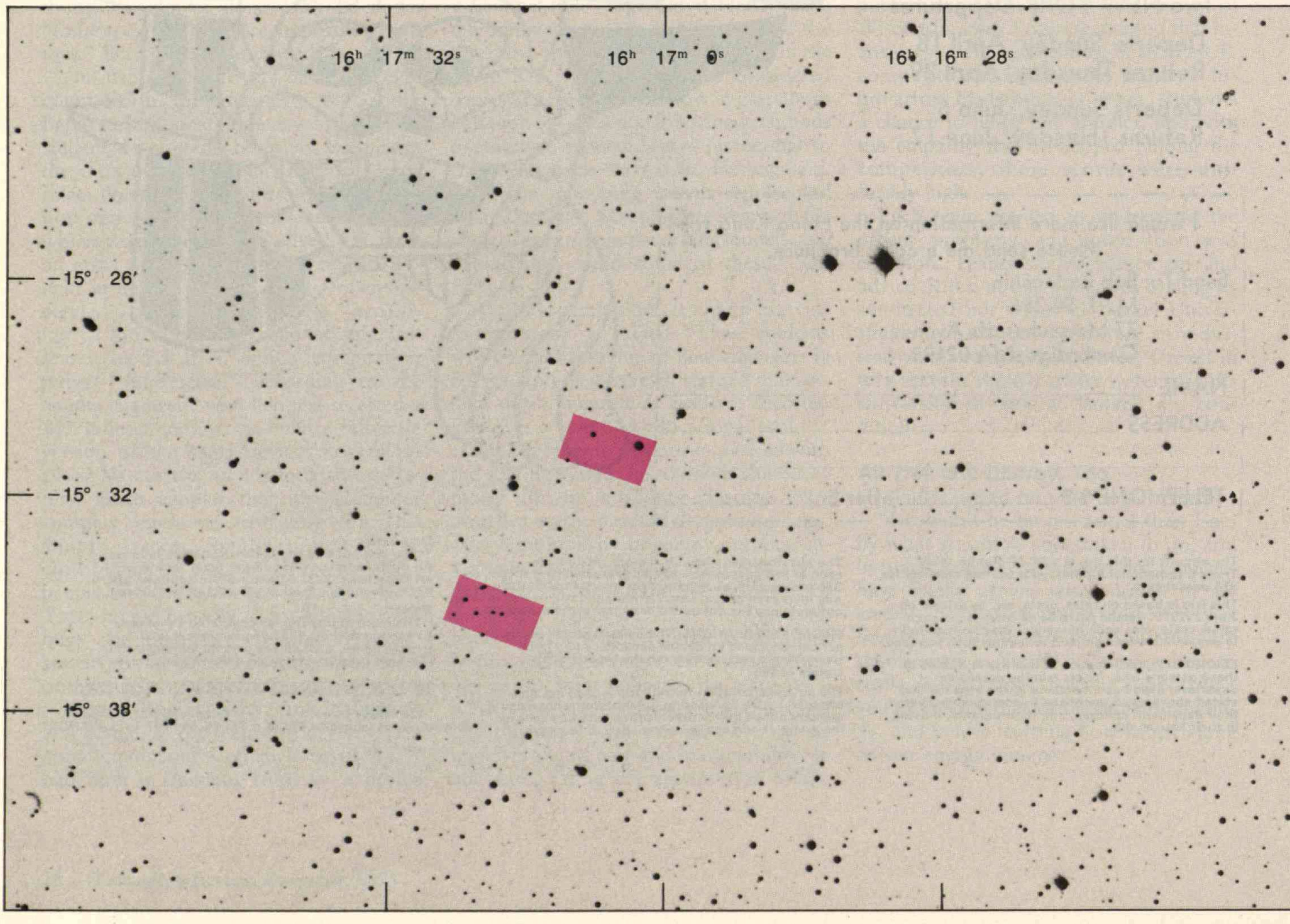
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Neutron stars and black holes may have been found in double-star systems that emit X-radiation.

Jeffrey E. McClintock
Center for Space Research
M.I.T.

The Marriage of X-Ray and Optical Astronomy

The prime source of our physics has been the order and regularity that man has watched in the heavens since the beginning of time. As the nineteenth-century mathematician and philosopher Henri Poincaré wrote in *The Value of Science:*

Think how diminished humanity would be if, under heavens constantly overclouded as Jupiter's must be, it had forever remained ignorant of the stars. Do you think in such a world we would be what we are? . . . You know what man was on the earth some thousands of years ago, and what he is today. Isolated amidst a nature where everything was a mystery to him, terrified at each unexpected manifestation of incomprehensible forces, he was incapable of seeing in the conduct of the universe anything but caprice . . . Today we no longer beg of nature; we command her, because we have discovered certain of her secrets and shall discover others each day. We command her in the name of laws she cannot challenge because they are hers . . . What a change our souls have undergone to pass from the one state to the other! Does anyone believe that, without the lessons of the stars, under the heavens perpetually overclouded that I have just supposed, they would have changed so quickly? Would the metamorphosis have been possible, or at least would it not have been much slower?

Astronomy has had a profound impact on human values. The heliocentric hypothesis of Copernicus and the observation by Galileo of blemishes on the face of the "perfect" sun had powerful influences on man's conception of his place in nature. As recently as 1924, our worldview was once again shattered by proof that our Milky Way Galaxy of a hundred billion stars is not the universe, but only a microscopic portion of it.

Fundamental discoveries continue to occur in the science of astronomy. The failure of the Michelson-Morley experiment to detect the absolute motion of the earth through space is a cornerstone of Einstein's theory of special relativity. The discovery in 1906 of a white dwarf star, Sirius B, which was known to be more than ten thousand times as dense as lead, presaged the quantum-mechanical description of matter that was formulated by Fermi and Dirac. The discovery and study of cosmic rays was in the forefront of elementary particle physics until about 1950; even today, the powerful accelerators at Batavia and Stanford at best produce particles that are a billion times less energetic than the highest-energy cosmic rays that have been detected. The radiation from the Crab Nebula, emitted by electrons moving at incredible speed through a maze of magnetic fields, was first predicted and then, in 1953, observed by Russian astrophysicists; this strange light is now generated routinely on earth. The discovery and continuing study of pulsars and quasars in the 1960s and 1970s have continued to force physicists to the frontiers of knowledge. And most recently have come observations in an infant branch of astronomy, X-ray astronomy.

Today about 200 celestial X-ray sources have been detected. About 30 of them have been optically identified, and among these 30, there are several distinct classes of objects. Some of the X-ray emitters within our galaxy are large stellar remnants containing hot gas; they continue to broadcast X-radiation thousands of years after a supernova explosion. Others include a mysterious region a thousand light-years in diameter at the very center of our galaxy, and binary star systems composed of an ordinary star with a radius of more than a million kilometers and a nearby superdense companion — a neutron star, black hole, or white dwarf. Outside our galaxy the diversity is even greater: quasars; so-called Seyfert galaxies, which contain very active nuclei; radio galaxies; and vast regions which extend over several million light-years at the center of rich galaxy clusters and contain several hundred galaxies.

Many thousand more sources will be detected by 1985, and it is likely that optical identifications will be made for a majority of them. Yet before 1962, conventional wisdom held that any search for celestial X-ray sources other than our sun was doomed to failure. The sun produces at most a millionth as much X-radiation as optical radiation; a similar source of X-rays would be totally undetectable at the most modest stellar distances. Nevertheless, a group lead by Riccardo Giacconi of American Science and Engineering and Bruno Rossi of M.I.T. obtained support from the Air Force to fly a rocket payload

The search for Scorpius X-1. In 1962, X-radiation was detected from the constellation Scorpius. Researchers began efforts to match the X-ray source to an object visible at optical wavelengths. In 1964, Bowyer *et al* restricted the source's position to within the yellow circle superimposed on the top photograph; a year later, Clark *et al* placed it inside either of the two boxes shown in blue; in 1966, Fisher *et al* placed it inside the box shown in orange. Finally, later in 1966, Gursky *et al* made a measurement sufficiently restrictive to allow an optical identification of the X-ray source; it was placed within one of two boxes shown in red in both photographs (the bottom photograph is an enlargement). The upper of these two red boxes contains a peculiar flickering star near its right border.

that was designed primarily to detect solar X-rays fluoresced from the moon's surface. The moon was not detected, but to everyone's astonishment, a powerful source of X-radiation *was*. It came from the direction of the Galactic center. The experimenters made a strong case for the existence of a celestial source for the X-radiation, ruling out any known terrestrial origin. However, the direction to the source and limits on its angular size were only crudely determined, so one could only guess whether the source was in the Galactic center 30,000 light-years from earth, or was perhaps a star-sized object only a few light-years distant. We now know this source by the name Scorpius X-1; the name signifies the first X-ray source discovered in that constellation. It is a star; its X-ray energy output is about ten thousand times the total energy output of our sun, and its distance is a few thousand light-years.

Distances Within Our Galaxy

Unaided by instrumentation and abstract concepts, man can perceive only two dimensions in the sky. Most astronomers of antiquity thought of the heavens as a spherical shell with all the stars located at the same fixed distance, as if on the domed ceiling of a modern planetarium. The Greek Heracleitus, for one, imagined the sun to be 10 miles in diameter and 1,000 miles distant, and concluded that the sun is a ball of fire which is extinguished in the ocean each night and rekindled in the morning. Clearly, a knowledge of distance is the underpinning of any cosmology. Only a distance scale can transform the heavens into a deep abyss.

Isaac Newton and others roughly estimated the immense distances to the nearest stars by asking how distant the sun would have to be to appear as an average bright star. It was not until the nineteenth century that instruments of sufficient precision became available to measure the small angular displacements of the very nearest stars relative to the distant stars that are caused by the earth's motion around the sun. The angular shift of a given star's position for a baseline of one earth-sun distance (eight light-minutes) is known as its parallax, and the distance to that star is simply the earth-sun distance divided by the parallax. One of the first such measurements was performed by Bessel on the star 61 Cygni. On many nights during the observing seasons of 1837 through 1840, he carefully measured the angular distance of 61 Cygni from two reference stars located eight and 12 minutes of arc away. The mean error for an evening's observations was only 0.14 arc-seconds, and the parallactic displacement of 61 Cygni relative to each of the two reference stars could clearly be seen to trace out a circle during each observing season. In 1838 Bessel found the parallax to be 0.31 arc-seconds, and in 1840 to be 0.25 arc-seconds, which corresponds to 590,000 earth-sun distances, or about nine light-years.

This triumph was praised by John Herschel in awarding Bessel the gold medal of the Royal Astronomical Society: "I congratulate you and myself," Herschel said, "that we have lived . . . to see the great and hitherto impassable barrier to our excursions into the sidereal universe [overlapped], that barrier against which we have chafed so long and so vainly . . . It is the greatest and most glorious triumph which practical astronomy has ever witnessed."

All stars easily visible to the naked eye now have known parallaxes. Unfortunately, the modest earth-sun baseline and present instrumentation do not allow us to reach out to distances greater than a few hundred light-years, now known to be less than one per cent of the distance to the center of our galaxy. Still, the distance and the observed brightness of any nearby star enabled astronomers to compute its intrinsic luminosity — that is, its rate of energy output. As a consequence, it was quickly realized that there is a wide range of stellar luminosities. For example, Alpha Centauri and Rigel appear equally bright in earth's sky, although Rigel is a hundred times more distant and ten thousand times more luminous.

The next step outward to greater distances was derived from the classification of stars, first according to color and later according to spectra. Differences in color had been known since the time of Ptolemy, and visual determinations of color for several thousand stars were carried out throughout the nineteenth century. A far more important development came with the study of stellar spectra, which disclose the diversity in the nature of stars. As early as 1823, Fraunhofer had described the spectra of Castor and Sirius and distinguished them from the solar spectrum. In the years 1863 to 1868, Secchi observed the spectra of more than 4,000 stars, and found that with few exceptions they could be classified into four types on the basis of the strengths and widths of a large number of spectral lines. By studying the nearby stars of known distance, it was discovered that similar spectra often imply nearly equal intrinsic luminosity. Therefore, the spectrum, which can be measured to much greater distances than can the trigonometric parallax, yields a good measure of a star's luminosity, and this, combined with the observed brightness, yields the distance. Distances determined in this way are known as spectroscopic "parallaxes." They are more uncertain than the trigonometric parallaxes determined for the nearest stars because they rely on the science of spectral classification, which contains a strong touch of art. However, the method of spectroscopic parallax can reach out more than a hundred times farther to a volume a million times greater, and hence provides an estimate of the distances to almost all the normally luminous stars within our galaxy.

There are many other techniques of distance determination within our galaxy, such as measurements of light absorption by interstellar gas and of the relation between pulsation period and luminosity in a class of stars known as Cepheid variables. However, all these specialized methods rely on the distances determined by trigonometric parallax and spectral classification.

The Optical Identification of X-Ray Sources

The X-ray astronomer can use the optical astronomer's distance scale and knowledge only if he can identify a source of X-radiation with an optical object. Since optical telescopes detect millions of celestial objects per square degree, it is plain that the X-ray astronomer must pinpoint the source of X-rays to high precision. This has proved difficult; at present, only about a fifth of the known X-ray sources have likely optical counterparts.

By 1964 about a half dozen X-ray sources had been detected, but none had been optically identified. In that year a beautiful observation was performed by Herbert Friedman and his collaborators at the Naval Research Laboratories which unambiguously identified the X-ray source Taurus X-1 with the Crab Nebula supernova remnant. The observers used the edge of the moon as a precisely positioned shutter, and observed the X-ray in-

tensity of Taurus X-1 diminish to zero as the moon swept over the Crab. (This powerful technique of lunar occultation was also used in 1962 to determine an accurate position and an optical counterpart for the radio source 3C 273, the first of the quasars to have its baffling optical radiation recognized as a simple set of spectral lines in an unexpected position: highly shifted toward the red end of the spectrum.)

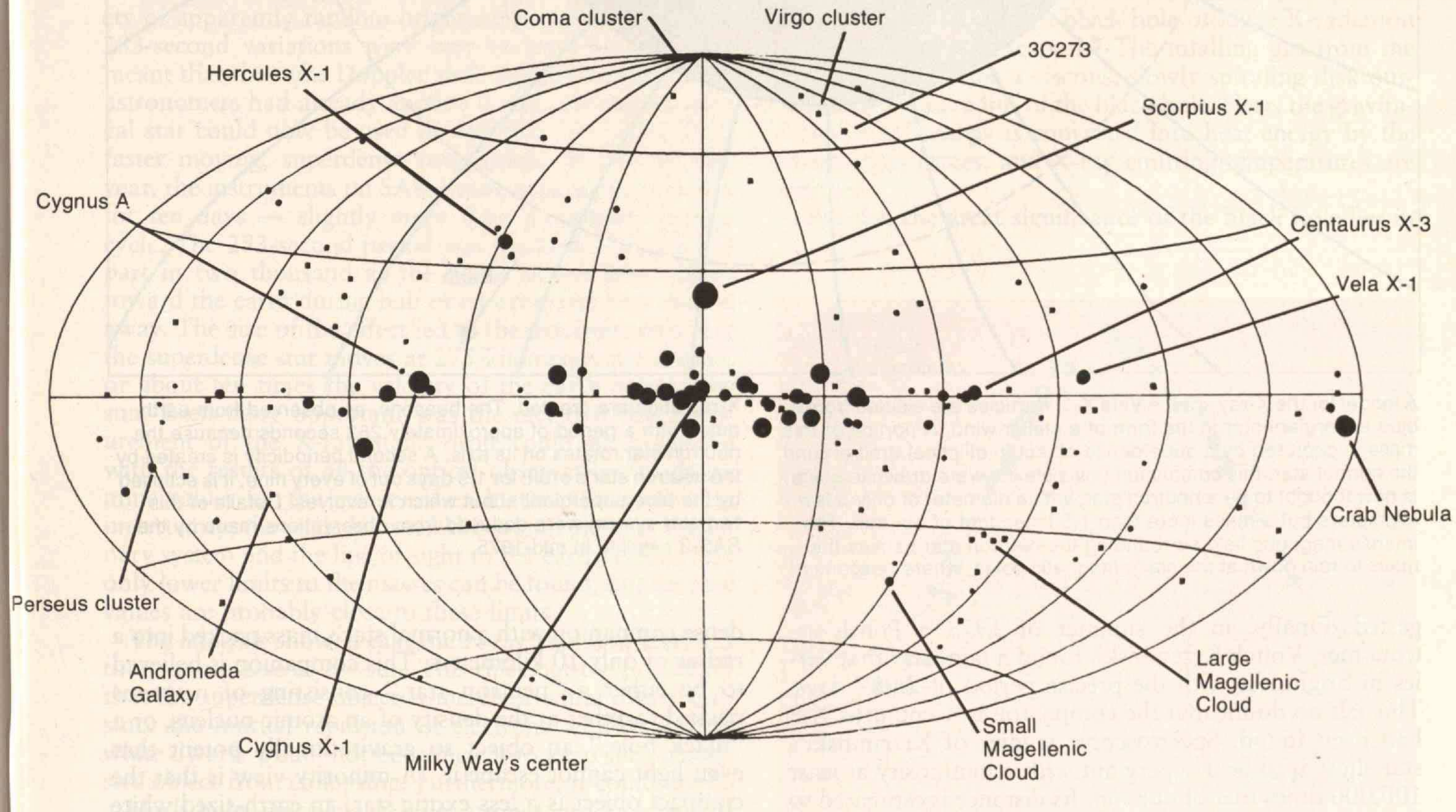
The second optical identification of an X-ray source did not come until 1966, a year in which the position of Scorpius X-1 was refined to a small region in the sky, containing only a couple of stars. A peculiar blue flickering star stood out immediately as an almost certain identification for Scorpius X-1. Once this had been established, optical techniques were used to estimate a distance of several thousand light-years. This implies an X-ray luminosity for this remarkable object of more than a billion times the X-ray luminosity of the sun, or more than a thousand times the total luminosity of the sun at all wavelengths.

Scorpius X-1 is located 24 degrees above the plane of our Galaxy — a location where the density of stars is relatively low. However, most of the strong X-ray sources are located within a few degrees of the Galactic plane (as shown in the illustration below), where the density of stars is about 10 times greater, making the search for optical counterparts of X-ray sources far more difficult. Moreover, the search is often seriously handicapped by the presence of a dust lane which is strongly concentrated in the plane of our Galaxy. The dust makes it impossible to peer into the heart of our Galaxy or beyond at optical wavelengths, and it is likely that a number of the Galactic X-ray stars will never be optically identified.

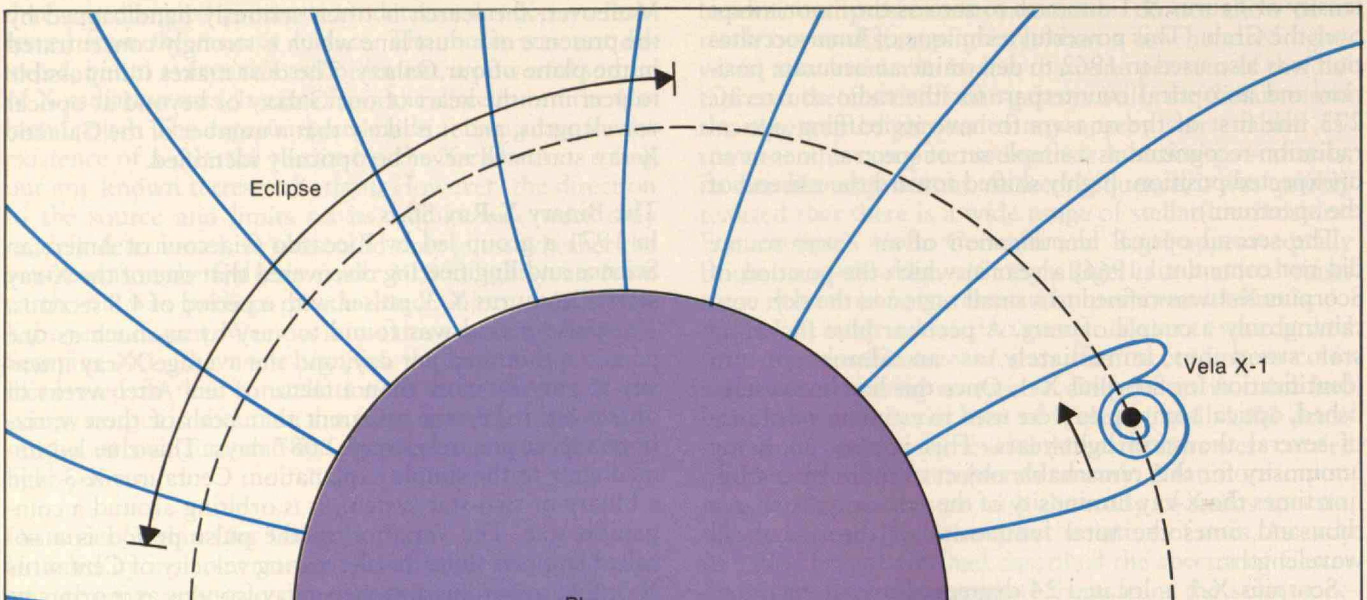
The Binary X-Ray Stars

In 1971 a group led by Riccardo Giacconi of American Science and Engineering discovered that one of the X-ray stars, Centaurus X-3, pulsed with a period of 4.8 seconds. The pulse period was found to vary by as much as one part in a thousand per day, and the average X-ray intensity to vary by more than a factor of ten. After weeks of observing, it became apparent that both of these variations repeat precisely every 2.087 days. This clue led immediately to the simple explanation: Centaurus X-3 is in a binary or two-star system; it is orbiting around a companion star. The variation in the pulse period is a so-called Doppler shift: the alternating velocity of Centaurus X-3, first toward us and then away from us as it orbits its companion, causes changes in the arrival times of the pulses observed at the earth. Meanwhile, the variations in the X-ray intensity are due to the eclipse of the X-ray star by the companion.

The companion to Centaurus X-3 remained elusive, however. Several false optical identifications were sug-



The X-ray sky. Objects emitting photons with energies from two to 10 thousand electron-Volts are plotted on Galactic coordinates; the horizontal axis is the plane of the Milky Way Galaxy. Some of the X-ray sources are rich clusters of galaxies in the constellations Coma Berenices, Virgo, and Perseus. Others are single galaxies, among them Andromeda, the galaxy closest to the Milky Way, and the Large and Small Magellenic Clouds, satellites to our own galaxy. Yet other sources, such as 3C273, are quasars — starlike objects as observed from earth that are, however, believed to be very distant. The Crab Nebula is the remnant of a star's explosion 5,000 light-years from earth. Cygnus A is a giant radio-emitting galaxy that also emits X-radiation. Scorpius X-1 has been identified with a blue, flickering star that has many of the characteristics of an old nova. Hercules X-1, Centaurus X-3, Vela X-1, and Cygnus X-1 represent the class of X-ray sources discussed in this article: binary star systems that include a normal though massive star and a small, superdense companion, now believed to be either a neutron star (Hercules X-1, Centaurus X-3, and Vela X-1) or possibly a black hole (Cygnus X-1).



A model for the X-ray source Vela X-1. Particles are ejected from a blue supergiant star in the form of a stellar wind. A portion of this mass is captured by a superdense object in elliptical orbit around the normal star; this companion (invisible if it were drawn to scale) is now thought to be a neutron star, with a diameter of only a few kilometers but a mass more than 1.5 times that of our sun. The intense magnetic field surrounding the neutron star causes the mass to rain down at the star's magnetic poles, where beacons of X-radiation are created. The beacons, as observed from earth, pulse with a period of approximately 283 seconds because the neutron star rotates on its axis. A second periodicity is created by the neutron star's orbit: for 1.9 days out of every nine, it is eclipsed by the blue supergiant about which it revolves. Details of this two-star system were deduced from observations made by the SAS-3 satellite in mid-1975.

gested. Finally, in the summer of 1973 a Polish astronomer, Vojtek Krzeminski, found a faint star that varies in brightness with the precise period of 2.087 days. This left no doubt that the companion to Centaurus X-3 had been found. Spectroscopic studies of Krzeminski's star show it to be a supergiant with a luminosity at least 100,000 times that of our sun. Its distance is estimated to be about 30,000 light-years. The distance and observed X-ray intensity give a luminosity for the X-ray source of 10,000 times the total luminosity of the sun.

Since the discovery of the binary nature of Centaurus X-3, seven other X-ray sources have been shown to be in binary systems, three of which pulsate periodically. The two-star systems are now believed to include an ordinary star with a radius of 10^6 kilometers, and a nearby superdense companion with a normal star's mass packed into a radius of only 10 kilometers. This companion is believed to be either a "neutron star," consisting of neutrons packed together at the density of an atomic nucleus, or a "black hole," an object so gravitationally potent that even light cannot escape it. (A minority view is that the compact object is a less exotic star, an earth-sized white dwarf.) The enormous X-ray power, — 10^4 solar luminosities — is produced by what at first sight appears to be a very unlikely process — the conversion of gravitational energy first to kinetic energy and ultimately to disordered heat energy. Gas leaves the large star and is attracted to the collapsed star, where the gravitational field is immense. In falling toward it, the gas is enormously accelerated and heated, and emits the observed

X-radiation. Only a modest rate of mass transfer — 10^{-8} solar masses per year, corresponding to one of earth's mountains per second — is required, for the process is an order of magnitude more efficient than nuclear fission or fusion. In 1975, the effects of the partial fission of only a few pounds of plutonium are well known and chilling. In those terms, the conversion of a mountain of material into thermal energy each second in a process that is ten to one hundred times more efficient can only be regarded as collosal. The net result is an X-ray flux of about 10^{37} ergs per second.

The sources that are precise clocks — Centaurus X-3 (4.84239 seconds), Hercules X-1 (1.23782 seconds), and Vela X-1 (282.8916 seconds) — are presumably rotating neutron stars with magnetic fields offset from the axis of rotation. The infalling gas is funneled along the magnetic field lines and driven into the star at the magnetic poles, where X-rays are generated. As the star rotates, the X-rays from the hot polar regions sweep across the sky. Such regular pulsations are not possible for a black hole, where any off-axis magnetic field is quickly destroyed.

Neutron Stars and Black Holes

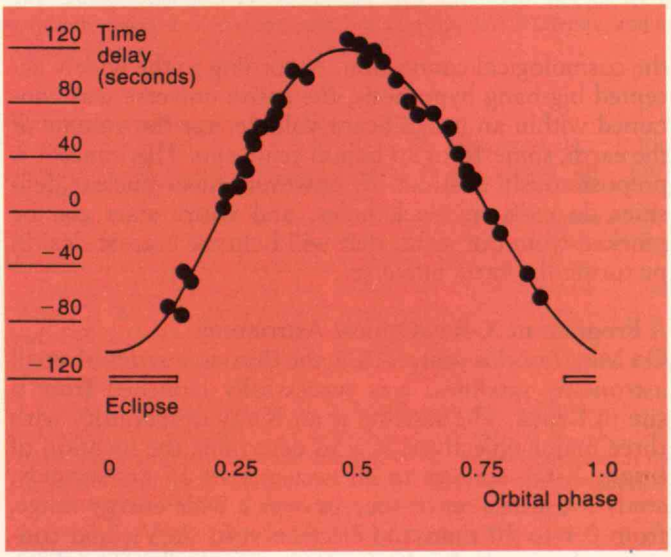
Vela X-1 is an eclipsing binary X-ray star which has recently taught us some new nuclear physics. In June of this year, M.I.T. scientists scrutinizing data from the SAS-3 satellite found that the X-ray intensity of Vela X-1 was varying rhythmically with a period of 283 seconds — this in addition to its regular nine-day eclipse cycle and a variety of apparently random brightenings and fadings. The 283-second variations were very exciting because they meant that the same Doppler shift analysis which optical astronomers had already applied to the companion optical star could now be used to determine the orbit of its faster moving, superdense companion. In July of this year, the instruments on SAS-3 were pointed at Vela X-1 for ten days — slightly more than a complete orbital cycle. The 283-second period was found to vary by one part in two thousand as the X-ray source first rushed toward the earth during half of its orbit and then rushed away. The size of the effect led to the determination that the superdense star moves at 275 kilometers per second, or about ten times the velocity of the earth around the sun. Even more important was the fact that this measurement of the X-ray star's orbit could be combined with the results of all the optical observations to determine values for the masses of each star. One remaining uncertainty, the angle between the orbital plane of the binary system and the line of sight to the earth, means that only lower limits to the masses can be found, but the true values are probably close to these limits.

The analysis showed that the X-ray star is at least 1.5 times as massive as the sun. This rules out the possibility that the superdense object is merely a white dwarf star, since the mutual repulsion of electrons which supports white dwarfs would not be sufficient to keep such a massive object from collapsing. Furthermore, it could not be a black hole, since black holes cannot produce regular pulsations. Thus, the observations led to the conclusion that Vela X-1 contains a massive neutron star spinning on its axis once every five minutes and circling its giant companion once every nine days. In addition, this precise value of the mass of a neutron star gives physicists the first hard data with which to test their models of the properties of nuclear matter at the extreme densities which exist inside the star. In fact, several previously popular hypotheses must be abandoned because they cannot explain neutron stars as massive as this one. In other words, Vela X-1, a double star system 4,000 light-years away, has told us something new about the subatomic structure of matter.

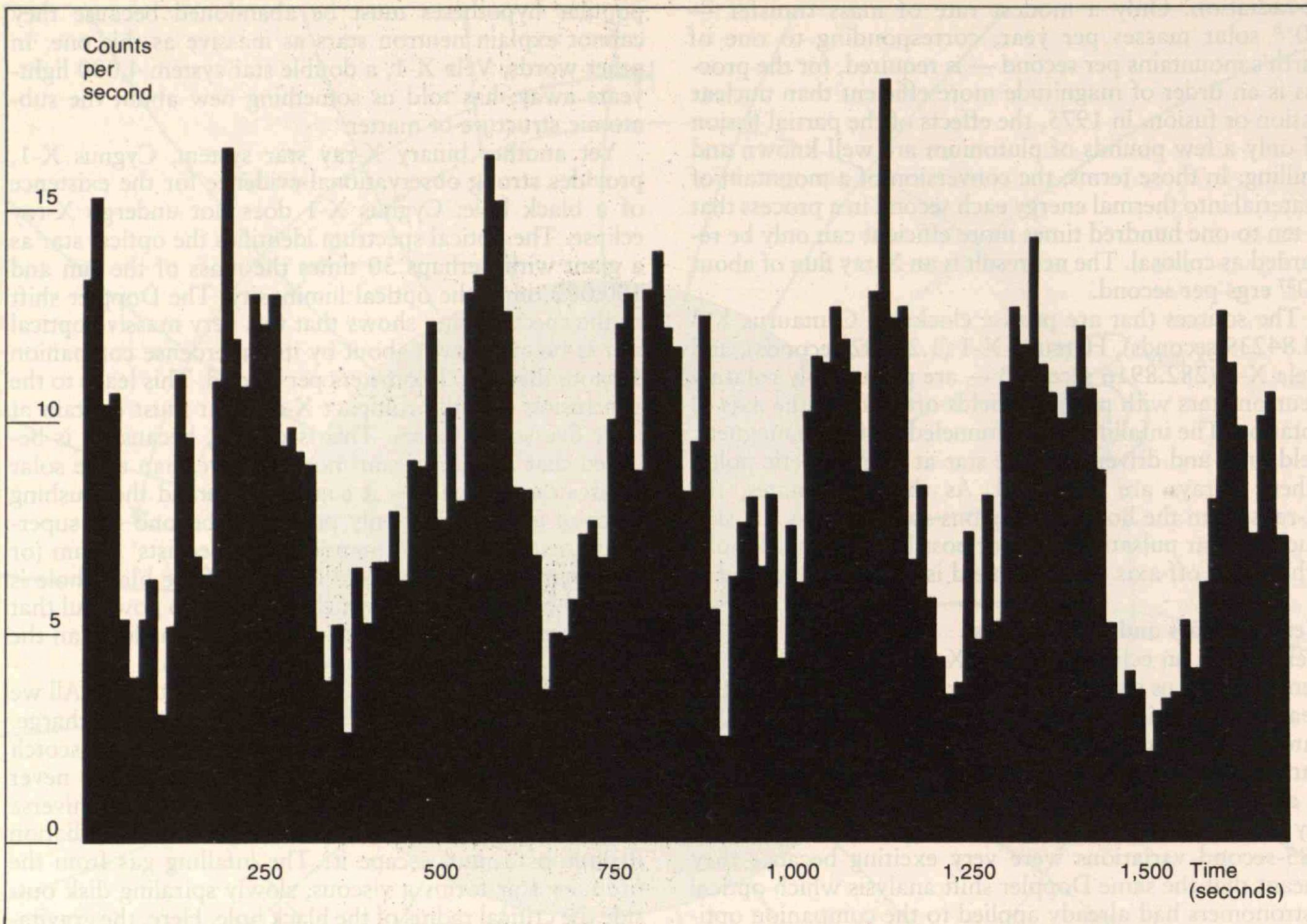
Yet another binary X-ray star system, Cygnus X-1, provides strong observational evidence for the existence of a black hole. Cygnus X-1 does not undergo X-ray eclipse. The optical spectrum identifies the optical star as a giant with perhaps 30 times the mass of the sun and 100,000 times the optical luminosity. The Doppler shift of the spectral lines shows that this very massive optical star is being thrown about by its superdense companion at more than 100 kilometers per second. This leads to the conclusion that the compact X-ray star must contain at least five solar masses. This is crucial, because it is believed that a neutron star more massive than three solar masses cannot exist — it cannot withstand the crushing force of gravity. The only possibility beyond the superdense neutron state of matter is the theorists' dream (or nightmare), the black hole. The size of the black hole is defined by the radius at which gravity is so powerful that light cannot escape. This size is slightly smaller than the size of a neutron star — several kilometers.

What is inside the black hole? We cannot learn. All we can ever know about it are its mass, rotation, and charge. We can feed a black hole anything whatsoever — scotch and soda, radioactive wastes, antimatter. It will never protest, and it will remove the stuff from our universe forever. Then how can a black hole produce X-radiation if photons cannot escape it? The infalling gas from the ordinary star forms a viscous, slowly spiraling disk outside the critical radius of the black hole. Here, the gravitational infall energy is converted into heat energy by the viscous gas forces, and X-ray emitting temperatures are reached.

For me, the great significance of the black hole lies in



The changing arrival time of X-ray pulses from Vela X-1. The changes occur because the source moves toward and away from the earth in the course of its orbit, thus altering the distance that its pulses must travel to reach detectors on the SAS-3 satellite. "Orbital phase" marks the position of the source: at 0.5, it is closest to earth, and at 1.0 and 0 (the same place in its orbit), it is farthest away. From these data, the appearance of the oribit and the orbital velocity of the X-ray source were determined.



Arrival rates of X-ray photons from Vela X-1, as recorded last June by a detector on the SAS-3 satellite. Five full cycles of the source's pulsation are shown, as well as portions of two further cycles at the left and right of the data plot. Analysis of variations in the arrival times of such pulses led to the determination of the X-ray source's orbit, as illustrated on the previous two pages. From the nature of this orbit, the mass of the source could be determined. This in turn led to the deduction by theoreticians that Vela X-1 is a neutron star; it is too massive to be a collapsed star called a white dwarf, yet it cannot be a black hole, for that would preclude the observed pulsations.

the cosmological connection. According to the widely accepted big-bang hypothesis, the entire universe was contained within an insignificant volume, say the volume of the earth, some 10 to 20 billion years ago. This concept is preposterously abstract. If, however, super-nuclear densities do exist in black holes, and entire stars can be plucked from our sight, that will help me a great deal in picturing the early universe.

A Program in X-Ray/Optical Astronomy

On May 7 of this year, SAS-3, the third in a series of small astronomy satellites, was successfully launched from a site in Kenya. The satellite is an X-ray observatory with three major objectives: it is to determine the location of bright X-ray sources to an accuracy of 15 arc-seconds; study a selected set of sources over a wide energy range, from 0.1 to 50 thousand electron-volts (keV); and continuously search the sky for X-ray novae, flares, and unexpected X-ray phenomena. The Principal Investigator is George W. Clark, Professor of Physics at M.I.T., and the Project Scientist is William F. Mayer, Jr., also of M.I.T. The scientific half of the observatory was built for the National Aeronautics and Space Administration by the M.I.T. Laboratory for Space Experiments.

At the time of writing (early October), the satellite has made 2,500 orbits, each yielding about 6 million bits of information. Once each orbit, the data are played back from an on-board tape recorder to a tracking station in Quito, Ecuador, then transmitted to Goddard Space Flight Center in Maryland, and finally to a minicomputer at the M.I.T. Center for Space Research. We receive the data at M.I.T. about 5 minutes after its reception at the tracking station; and after an additional 45 minutes of computing time the orientation of the observatory relative to the stars has been computed to an accuracy of one arc-minute, and data from ten X-ray detectors have been plotted as a function of time. The results thus far are gratifying. We have discovered three new low-energy (0.1-1 keV) X-ray sources; two are point-like and one is extended. We have discovered the 283-second periodicity in Vela X-1 and "weighed" the massive neutron star in that system. The locations of about a dozen X-ray sources have been greatly improved.

The optical side of the X-ray/optical program began in 1972 when Claude R. Canizares of M.I.T. and the author began making observations of the X-ray stars at M.I.T.'s Wallace Observatory and at the Kitt Peak National Observatory near Tucson. We were searching for rapid optical pulsations or flickering in the X-ray stars. At that time

we hungered for an instrument with high spectral resolution, large spectral coverage, and high time resolution, and for an observatory with a telescope of moderate size located at a good site. Through good fortune we now have both. The instrument consists of a spectrograph built by Doran Bardas, an M.I.T. graduate student, and a television camera-computer system built by Patrick Peterson, a staff member at M.I.T. The system allows us to label each detected photon with its arrival time to an accuracy of about 100 milliseconds, and with its wavelength to an accuracy of about one Ångstrom. The observatory, recently named the McGraw-Hill Observatory, is a joint venture involving three institutions: the University of Michigan, Dartmouth College, and M.I.T. It is located on Kitt Peak near Tucson, Arizona, and its 1.2-meter telescope was moved there from cloudy Ann Arbor, Michigan, largely through the perseverance of W. A. Hiltner, Chairman of the Astronomy Department at the University of Michigan and Director of the new observatory, and through the generosity of the McGraw-Hill Publishing Company. This is the first optical observatory established to study the X-ray sky. The observing program is tailored to support the M.I.T. SAS-3 observing program.

Future Missions

Between now and 1980 the prospects for major discoveries in X-ray astronomy appear excellent. A large number of new satellite observatories have recently been launched or are in advanced stages of construction or planning. Somewhat surprisingly, both rocket and balloon-borne instrumentation continue to make substantial contributions to our knowledge. The short lead time (about six months) and the flexibility of rocket and balloon programs allow novel ideas to be tried quickly, while satellite missions inevitably consume four to ten years from proposal to launch.

The second High-Energy X-Ray Observatory, HEAO-B, is scheduled for launch in 1978. This ambitious mission constitutes a revolution in X-ray astronomical technique — it will produce X-ray images of optical quality. This is feasible because X-rays of modest energy (less than about four keV) can be reflected from highly polished metal surfaces. It will be possible to rotate several different pieces of instrumentation into the focus of such an X-ray mirror: a high-resolution camera (about one arc-second), a moderate-resolution and wide-field camera, a high-resolution crystal spectrometer (an M.I.T. project), and a moderate-resolution solid-state spectrometer.

It would be difficult to describe adequately the great power of this mission. For example, the weakest detectable source will be about 10^7 times fainter than the brightest X-ray source, Scorpius X-1. This is a thousand-fold improvement in sensitivity over what has presently been achieved. It is equal to what is now possible at radio frequencies, and compares favorably to what is possible in visible light, almost four centuries after Galileo first peered through his telescope. The X-ray astronomers' capability has been achieved in less than two decades.

It is likely that the discoveries to be made by the powerful HEAO-B X-ray observatory will demand higher-quality optical observations than can be achieved from the earth's surface. Optical astronomers also will have much to gain by conducting their observations in space. The Large Space Telescope (LST), to be launched about 1980, is one of the most ambitious scientific projects ever attempted. The present plans call for an instrument of about 2.5 meter aperture. The observatory is to be launched and serviced by the Space Shuttle, and will be designed for about a decade of life in orbit. The space environment provides two immense advantages. First, because of the blurring produced by the atmosphere, ground-based telescopes can achieve a resolution of only about one arc-second. The LST will have an order of magnitude better resolution, and this will allow the study of objects a hundred times fainter than is possible using the largest ground-based instruments. Second, the orbiting telescope can be used over four decades of the electromagnetic spectrum, from 1,000 Ångstroms in the ultraviolet to one millimeter in the far infrared. The HEAO-B X-ray observatory will complement this by spanning the range from about three to 100 Ångstroms. From the earth's surface the atmosphere allows nothing to be studied at wavelengths below 3,000 Ångstroms, and only a few dirty windows exist above 20,000 Ångstroms. The LST and HEAO-B will smash the atmosphere's barrier between us and the heavens.

The LST will surely stand as one of mankind's greatest scientific achievements. But there is a deep fear in this era of tight budgets that the instrument may be reduced further in size (it was conceived as a three-meter instrument). Because the objects that the LST alone can detect are very faint, the instrument's size and light-gathering power are crucial. Any further reduction below the presently contemplated 2.5 meters will seriously cripple the mission.

As space observatories become increasingly expensive, and as the time to build such facilities grows longer and longer, I am reminded of the situation described by Emerson: "If we only saw the starry heavens once in a hundred years we should spend years in preparing for the vision."

Jeffrey E. McClintock is a research staff member in the M.I.T. Center for Space Research. He did his undergraduate work at Stanford University, and received his Ph.D. in physics from M.I.T. Dr. McClintock is currently engaged in analyzing the data from the SAS-3 satellite, and in optical observations of X-ray sources.

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An exploded star's remnant is emitting more energy in death than the star did in life.

Hale Bradt
Professor of Physics
M.I.T.

The Crab Nebula: A Unique Astrophysical Laboratory

In the spring of the year 1054, a fascinating drama was occurring in the sky; astronomers might have watched it, had the telescope been available to them. A star in the constellation Taurus was trying to avoid a violent death. For some billion years, it had been burning nuclear matter at its core. This had heated the star, and created an outward pressure in the stellar gas which balanced the tremendous inward pull of gravity. First the star had burned hydrogen to make helium, as our sun is now doing. Then it had burned helium, and, in turn, heavier and heavier elements were created until iron was formed at the core. The iron nucleus is the most stable of all nuclei and cannot undergo further transformations. Thus the burning at the core came to a halt.

The star began to shrink under the influence of gravity; gravitational potential energy was converted to kinetic energy, and the core began to heat up. At a temperature of a few billion degrees Kelvin, the iron nuclei in the core began to break into helium nuclei, or possibly neutrons. This process is endothermic — it soaks up energy, which is taken from the kinetic energy of the surrounding particles. That is, the process cooled the gas and reduced the pressure in the core. Thus the star continued to shrink. Perhaps now the core's heating would build up enough pressure to forestall an uncontrolled collapse. Unfortunately, the disintegrating nuclei gobbled up the energy at too great a rate, and the central parts of the star fell inward in a catastrophic free-fall collapse which lasted only about a second.

However, in its death, the star became a spectacular celestial object, dramatically eclipsing its brilliance in life. As the stellar core collapsed, the outer parts of the star, no longer supported, also began to fall. As they fell, they heated up. They contained unburned nuclear fuel which violently exploded. Within weeks the emitted light became as intense as 10 billion suns — the star became nearly as luminous as all the stars in our Galaxy (the Milky Way system) combined.

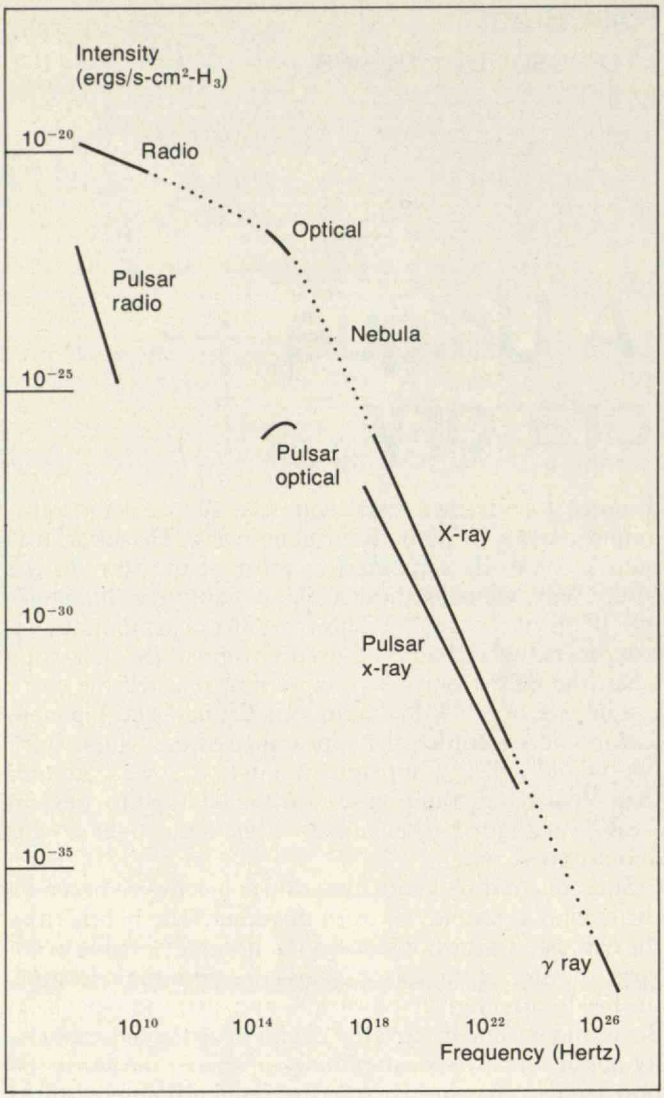
This particular star was situated about 5,000 light-years from earth — an immense distance compared to the distance to our own local star (the sun is eight light-minutes away, or about 10^{-5} light-years). However, it is quite close to us compared to most of the stars in the Milky Way, which is about 100,000 light-years in diameter. Thus it became a showcase for earthbound astronomers, who had not even invented the telescope when the light from the collapse first reached the earth late in June of 1054. In that month, Chinese and Japanese astronomers recorded the appearance of the "guest star" (we would call it a supernova). At first it was brighter than Venus and could be seen in the daytime for several weeks. As it faded, it remained visible in the night sky for about two years.

Subsequent discoveries about this object were paced by the technological advances of mankind. The debris from the explosion were not seen until it became possible to enlarge the size of the astronomer's eye with the telescope. In 1731, an English physician and astronomer, John Bevis, did so, and discovered a faint oval-shaped nebulosity about four by six arc-minutes in size in the constellation Taurus. (By comparison, the angular diameter of the moon is 30 arc-minutes.) He recorded it on a map of the sky that he prepared. In 1758, a French astronomer, Charles Messier, independently discovered it. He noted that it did not move relative to the stars, and included it as the first entry in his famous catalog of nebulosities *to ignore* — he was searching for comets! It is still known as Messier 1 or M1.

The first photographs of the nebulosity were taken in 1892. They showed much new detail: a central mass and intertwining filaments. In 1921, two photographic plates taken eight years apart were compared. An expansion of the size by about one per cent was noted. At this angular velocity, the nebulosity would have taken about 800 years to reach its observed size from an initial point explosion. In the same year, 1921, astronomers examining old Chinese records noted the reports of the 1054 guest star in the constellation Taurus. However, it wasn't until 1928 that the nebulosity, by now known as the "Crab Nebula," was associated with the 1054 guest star by the renowned astronomer Edwin Hubble. This association, in one stroke, showed astronomers that the nebulosity had once been a spectacular supernova. The present "age"* of the Crab Nebula, 921 years, is but a flash com-

The Crab Nebula in the constellation Taurus, as photographed by the 200-inch telescope at the Palomar Observatory. The nebula, some 5,000 light-years from earth, is the gaseous remnant of a star whose explosion was observed by Chinese astronomers in June of 1054 AD. Near the center of the nebula is a doublet of stars; the one at the lower right is now known to be a pulsar — a pulsating radiation source — and the stellar remnant of the exploded star. Its energy powers the emission of the entire nebula.

* The actual age is, of course, much greater because of the 5,000 years required for light to travel from the Crab to the earth. Since the light we now receive and study was emitted by the Crab 921 years after the supernova explosion, we refer to its age as being 921 years.



Energy spectra of the Crab Nebula and its associated pulsar, NP0532. The dashed lines are extrapolations into spectral regions where measurements have not as yet been made. The solid lines are measurements in radio, optical, X-ray, and gamma-ray frequencies; they show the emitted power per unit frequency interval. Accordingly, to obtain the total power emitted in a given spectral region, one must multiply by the bandwidth of interest. That bandwidth is far greater for X-rays than for optical photons — a fact hidden by the logarithmic plot shown here. On performing the multiplication, one finds that the X-ray power of the pulsar greatly exceeds its radio and optical power.

pared to the duration of its earlier life of a billion years or more as a normal star. Thus we now observe the remnant of this spectacular event from a "near" distance and "immediately" after it happened, a unique opportunity indeed.

The Discovery of Radio and X-Ray Emission

The advent of radio astronomy paved the way for the discovery in 1948 that the Crab Nebula is one of the brightest discrete radio sources in the sky. It was the first radio source to be identified with an optical source in the sky other than the sun. This identification was very important because, once so identified, the Crab Nebula could be studied in detail in both wavelength regions (radio and optical), and the physical conditions within the nebula could be determined with more confidence.

This capability was enhanced significantly in 1964, when scientists at the Naval Research Laboratory discovered that the Crab Nebula is also a copious emitter of X-rays. Again, in this wavelength region the Crab was the first non-solar celestial source to be identified with an optical object. The X-rays were observed to come from a broad region of the nebula, about two arc-minutes in angular size. Thus the source of the X-rays must be distributed throughout a large portion of the nebular material. These X-rays are photons with energies of several keV (thousand electron volts), compared to about two eV for optical photons. The discovery of these X-rays had to await the development of rockets and balloons which could lift detectors high above the earth's atmosphere, which is opaque to the X-rays.

The Crab was also found to emit high-energy X-rays at energies up to 60 keV in an M.I.T. balloon experiment carried out by George Clark in 1965. Subsequently gamma rays of energies up to 10^{11} eV per photon have been observed. Thus the Crab can now be studied over a tremendous dynamic range of photon energies. (The spectrum of energy flux as a function of frequency is shown at the left.) In total, the Crab emits 10^{38} ergs per second, or 25,000 times the total power emitted by our sun! Since the Crab was once a normal nuclear-burning star much like our sun, it follows that now, after exhausting its fuel and collapsing, it is broadcasting much more power than it did when its fuel tanks were full.

From whence comes this outpouring of energy? The total amount radiated by the Crab in 921 years is 3×10^{48} ergs, if we assume a constant output of 10^{38} ergs per second. Much higher luminosities at earlier times lead to higher estimates — 10^{50} to 10^{52} ergs. These energies approach the total rest-mass energy of a solar mass ($E = mc^2 = 2 \times 10^{54}$ ergs — the total energy content intrinsic to a star with the mass of our sun). In nuclear burning, only about one per cent of the nuclear rest-mass energy can be converted to kinetic energy of particles, and ultimately to radiant energy. Thus if 10 per cent of a solar mass underwent nuclear burning in the explosion, about 10^{51} ergs would be produced. This is only marginally enough to account for the total radiated energy from the Crab. Quite possibly it is not enough.

Gravitational energy, on the other hand, can easily provide the required energy. If a solar mass of material collapses until its density is comparable to that of an atom's nucleus, the result is an extremely compact "stellar nucleus" whose radius is only about 10 kilometers. (The radius of the sun is 700,000 kilometers.) The gravitational potential energy released by such collapse amounts to 2×10^{53} ergs, which easily satisfies our requirement for up to 10^{52} ergs. This final state of collapse, a 10-kilometer "nucleus," had been postulated in the 1930s as a possible stable state for a burned-out star. At the very high pressures within this object, all the protons would have been transformed to neutrons; hence it was called a "neutron star." Astronomers had long attempted to find evidence for its existence. As we shall see, it was the Crab Nebula that yielded the first clear evidence for such a remarkable object.

The statement that a gravitational collapse 921 years ago can provide sufficient energy to explain the outpouring of photons since that time is hardly the entire story. We must now explore how some of this energy is stored and eventually converted to photons centuries later. The unfolding of the correct picture required a series of new

observations and discoveries which have taken place over the past 20 years.

Synchrotron Radiation from the Crab

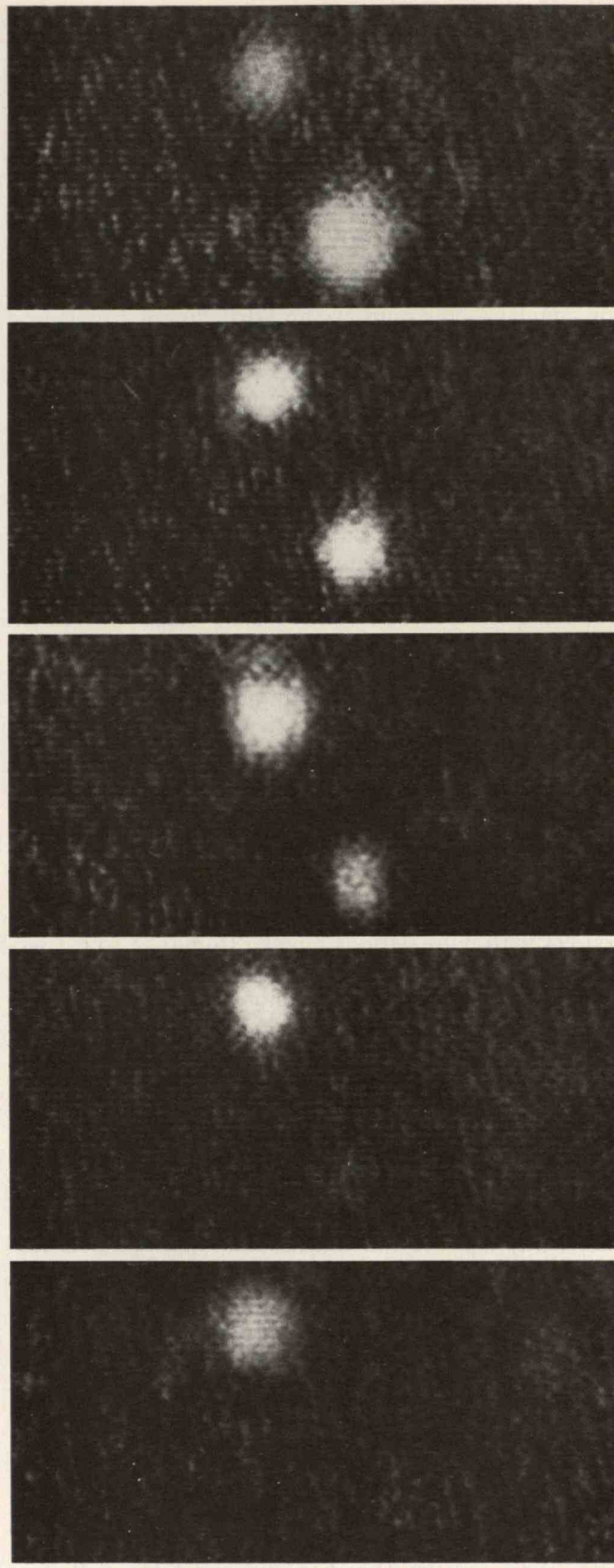
In an attempt to understand the mechanism whereby the emitted photons are created, I. S. Shklovsky proposed in 1953 that a process known as synchrotron radiation might be responsible. This phenomenon had been observed in electron accelerators, wherein high-energy electrons moving in a magnetic field spiral around the magnetic field lines and, by virtue of their continuing acceleration, emit electromagnetic radiation. At extremely high energies, when the electron velocity is very close to the velocity of light, the radiation is intense and highly beamed in the direction of the electron's motion at the instant it emits the radiation.

Shklovsky was led to his proposal by the problems he encountered in trying to explain the bluish central region of the Crab. The conventional explanation had been that it was due to emission by an extremely hot plasma — a gas of ionized atoms, in this case at a temperature of about 10^5 °K. But the light emitted by such a plasma should include discrete spectral lines — from hydrogen, for instance — and the Crab's light did not. Moreover, the model implied an extremely massive nebula — 20 to 50 solar masses. On the other hand, synchrotron radiation from a collection of speeding electrons of many different energies would yield a continuous photon spectrum with no emission lines. Also, the mass required would amount to only 10^{-10} solar masses.

Synchrotron radiation is expected to be highly polarized because of the forward beaming mentioned above and because the possible motions of the electrons are constrained by the magnetic fields. Accordingly, if these fields are uniform over a portion of the nebula which is large enough to be resolved by an earthbound telescope, the radiation from that portion of the nebula would show a net polarization. This suggestion led to independent observations in 1953 and 1954 by Dombrovsky and by Vashakidze that demonstrated the existence of a net polarization of the bluish optical light. The polarization over restricted regions of the nebula was later shown to be as high as 50 per cent. Following this, a search at radio energies also demonstrated a significant net polarization. More recently, polarization has also been observed at X-ray energies by scientists at Columbia University.

The existence of polarization in all three domains — radio, optical, and X-ray — confirms without doubt that synchrotron radiation is the dominant emission mechanism from the amorphous central region. The electrons must be extremely energetic, typically 10^{11} eV to emit optical photons and 10^{13} eV to emit X-rays. How do the electrons receive their energy? Could they have received it directly from the original explosion? The answer is emphatically *no*! Electrons of 10^{13} eV which emit X-rays would lose half their kinetic energy in only one to two years. For the optical radiation, the electron's emitting lifetime is on the order of 100 years. (The radio emission, however, presents no problem of this sort since the emitting lifetime exceeds the 921-year age of the Crab.)

These short lifetimes imply that there is a continuous injection and acceleration of electrons. What kind of continuous, ultra-high-energy accelerator could there be in the Crab Nebula? This question was the outstanding mystery of the Crab, and one of the major unsolved prob-



One flicker of the Crab pulsar, as recorded by E. Joseph Wampler and Joseph S. Miller at the Lick Observatory. The pulsar is easily visible in the topmost image of the sequence; in the bottom image it has turned off. Each photograph actually sums over many cycles of the pulsation: A disc with a slit cut in it was placed in the focal plane of a television-like imaging system. When the disc was rotated in synchrony with the 33-millisecond period of pulsation, only light from the same instant of the pulse cycle could contribute to each image. The variegated background is an artifact of the recording electronics.

lems of astrophysics from 1954 to 1968.

The Crab's Pulsar

Suppose that, in the initial collapse, a compact neutron star is indeed formed. Suppose further that angular momentum is conserved through the collapse, so that the initial slow spin rate of the original star is converted to fast spinning of the compact star. We can guess the final spin rate by noting that our sun rotates once every 27 days, and that the radius of the postulated neutron star is 70,000 times smaller than that of the sun. Then, conserving angular momentum, we find that the rotation period would decrease by a factor of 70,000 squared, yielding about 4×10^{-4} seconds, or 0.4 milliseconds, for the final spin period. Imagine a star rotating 2,500 times per second — wouldn't it fly apart? Probably it would, but not if it were a bit slower. A star with the sun's mass but a 10-kilometer radius is so tightly bound by gravity that it could spin as fast as 1,500 times per second without becoming gravitationally unbound.

Thus we see that angular momentum conservation and stellar collapse to neutron-star densities suggest that spin periods on the order of milliseconds might well be expected. Such a rotator would have an immense rotational kinetic energy, in excess of 10^{52} ergs for a one-millisecond rotator. That might be the means by which the gravitational-collapse energy could be stored and gradually given up to electrons (present in the nebular gas or on the neutron star's surface), which accelerate and subsequently emit the photons we observe.

This self-consistent picture, now known to be correct, developed under the stimulus of a series of discoveries. The first was the accidental discovery in 1968 of pulsars at radio frequencies. These were regularly pulsing radio sources with pulse periods ranging from 0.25 to 3.7 seconds. About a hundred of them are now known. Their discovery astounded the astronomical community; no such phenomenon was known prior to this. It led to the shared award of a 1974 Nobel Prize to one of the discoverers, Anthony Hewish of the University of Cambridge.

Several theories of the origin of these pulses were rejected as implausible. In contrast, spinning, compact stars seemed to be a tenable way to explain the regularity of the pulsing. The typical spin period of about a second was sufficiently rapid to rule out normal, large stars because they would fly apart. However, it was not sufficiently rapid to force one to the conclusion that the pulsars were as compact as the elusive neutron stars. They could have been white dwarfs. These are burned-out stars that have collapsed to the size of the earth.

White dwarfs were known to exist. They typically have masses on the order of one solar mass. The theories indicated that above about 1.4 solar masses, a dying star must continue its collapse to the 10-kilometer radius of a neutron star, the existence of which had not yet been demonstrated. But in the course of systematic searches for more radio pulsars, David Staelin and Edward Reifenstein, at M.I.T., discovered the fastest pulsar of all, right at the Crab Nebula. It had a spin period of 33 milliseconds, corresponding to a spin frequency of 30 rotations per second. Here then was a pulsar rotating so rapidly that if it were a white dwarf it would fly apart. It *must* be a neutron star! Thus again the Crab surprised the astronomical community, this time in 1968. The object was designated NP0532, the digits referring to its celestial longitude of 5 hours, 32 minutes. At about the same time, another fast pulsar (89 milliseconds) was found in the constellation Vela. This, too, was a convincing example of a neutron star.

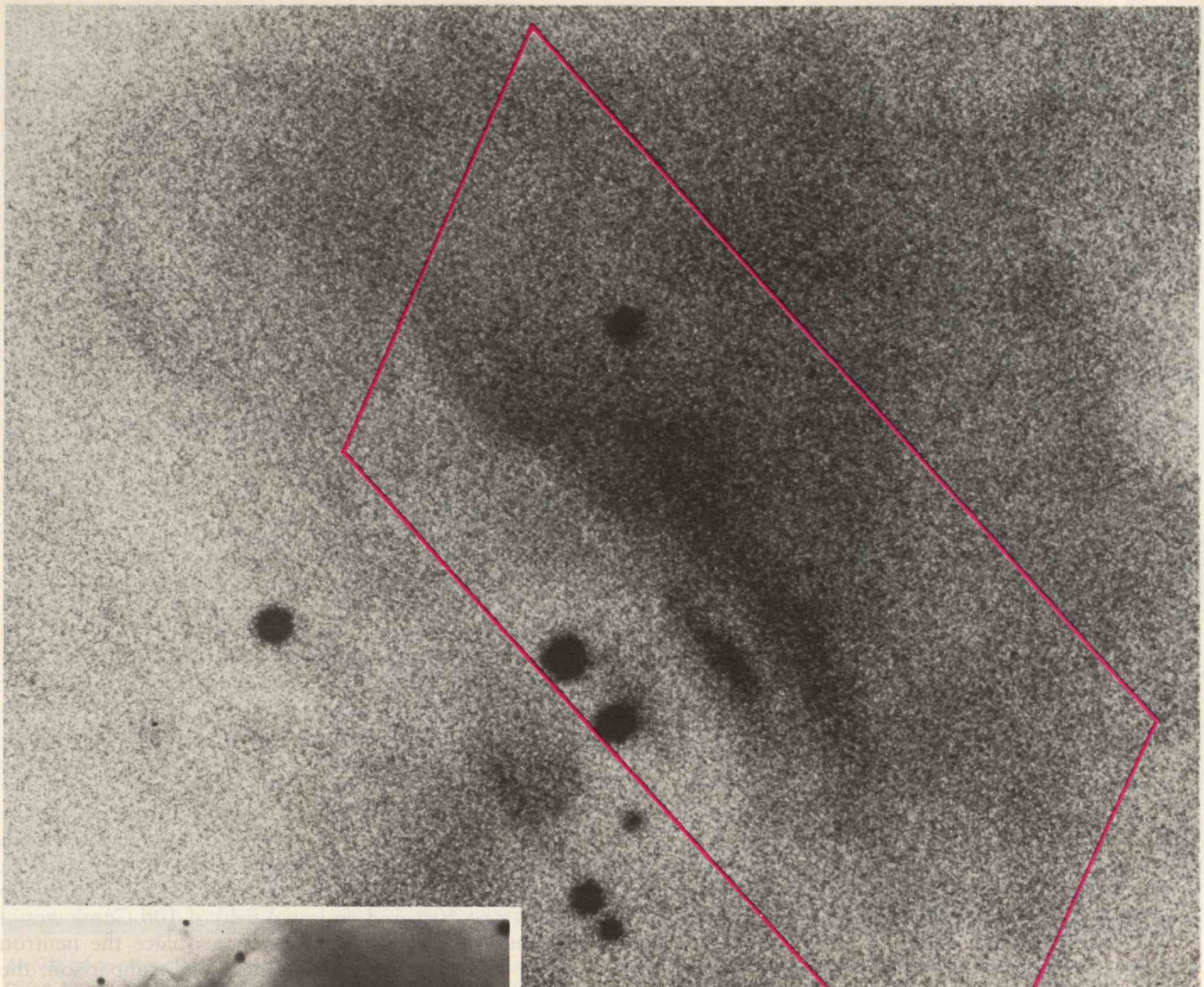
Within a few months of the radio discovery of NP0532, optical astronomers discovered 33-millisecond pulsing in the central part of the Crab Nebula. It was quickly narrowed down to the southwestern (lower right) partner of the close pair of stars at the center of the nebula. The star flashes on for about two milliseconds and again for four milliseconds during each 33-millisecond cycle. Astronomers had known of this star for years, and had even suspected that it was the energy source for the emitting electrons. In the meantime, it had been sitting there in photographs, flashing its secret to us all the time. It simply had never been observed with instruments of sufficient timing resolution: photographs averaged over many cycles of the flashing, the eye at the telescope averaged over several cycles, and photoelectric detectors commonly used by astronomers were not read out frequently enough.

The optical discovery was followed within a few months by the discovery of pulsing in X-rays by the group at the Naval Research Laboratory. An independent and nearly simultaneous observation from a rocket experiment conducted by Saul Rappaport and the author at M.I.T. confirmed this result and also demonstrated that the X-ray and optical pulses arrive at the earth simultaneously, within the timing precision of the experiment, about 0.3 milliseconds. This latter finding suggests that the optical and X-ray pulses were emitted simultaneously, as might be expected. Evidently, the X-ray and optical photons from a given pulse traveled side by side for 5,000 years and finished their journey within 300 microseconds of one another, even though a single X-ray has a thousand times more energy than an optical photon. This is consistent with the special theory of relativity, which tells us that, in a vacuum, *all* photons travel at a constant "speed of light," 3×10^{10} centimeters per second, regardless of their energy.

The profile of the X-ray pulse as obtained recently from the SAS-3 satellite is shown in the upper curve on page 41; the optical pulse shape is shown in the lower curve. As in the earlier rocket investigations, the pulsed X-rays are found to carry a full 10 per cent of the X-ray power from the entire Nebula. And since the X-ray power exceeds the total emitted optical and radio power, it is clear that the central pulsing star is important to the overall energetics of the Crab Nebula.

The Search for X-Ray Pulsing

The first M.I.T. experiment that detected the X-ray pulses was flown on an Aerobee rocket from White Sands Missile Range in New Mexico on April 27, 1969. The X-rays were detected with "proportional counters," a variant of the well-known Geiger tube. X-rays from the entire nebula were counted together, since it was impossible with available techniques to focus down onto the star in the manner that optical astronomers do. We simply limited the field of view of the detectors to about 20 degrees. The rocket was oriented with a preprogrammed gyroscopic and gas-jet system so that the Crab Nebula was within the field of view for the entire 190-second ballistic portion of the flight — the interval after the rocket engines had exhausted their fuel and before the payload began to reenter the atmosphere.



A source region for the Crab Nebula's X-radiation: about 70 per cent of the photons between 20 and 150 keV in energy emanate from the area bounded by the parallelogram, whose dimensions were determined from the lunar occultation data shown on page 42. Immediately above, the parallelogram is superimposed on a negative, that shows the entire nebula and was taken on the Hale Observatories' 200-inch telescope by Walter Baade in 1950. The same parallelogram is also superimposed on a photograph of the nebula's central region that was taken on the Lick Observatory's 120-inch telescope by Jeffrey Scargle; this image, too, is printed as a negative. The X-ray-emitting region appears to be aligned with the nebula's optical features.

The decision to conduct this experiment was not easy to make. At the time, radio and optical pulsing had been discovered from the Crab, but not X-rays. The discovery of optical pulsing had been very surprising; some 30 radio pulsars had been discovered, and optical astronomers had exhausted countless hours of telescope time in fruitless searches for their optical counterparts. Finally, it was the Crab that yielded the first and only optical pulsar. Would it also exhibit X-ray pulsing — bursts of photons that are a thousand times more energetic? Probably not; one wouldn't expect a radio transmitting antenna to emit visible light, much less X-rays. Furthermore, we were limited to one or two rocket flights per year, providing an annual total of about six minutes of observation time. We plainly had to choose the targets of our observations with care to optimize the scientific yield. The extreme importance of understanding the Crab Nebula carried the day, and we proceeded with dispatch to prepare our existing payload for the observations.

Our desire to compare the arrival times of the optical and X-ray pulses, should the latter even exist, required some complicated planning. First it was necessary to record precisely the arrival times of the X-ray photons. This was relatively easy, since White Sands Missile Range has the facilities to record routinely and with excellent precision the data telemetered from the rocket. We simply had to insure that those facilities were used. We also required nearly simultaneous optical observations. Astronomers at the University of Texas immediately agreed to make the required observations. Later, it turned out that the Hale Observatories' 200-inch telescope on Mount Palomar, California could also be used for this measurement. This was an important contribution since either observatory could be clouded over, and it is difficult to postpone a rocket launch. It was quite a thrill for us to carry out observations associated with this famous telescope.

The observations in Texas, New Mexico, and California took place successively as the Crab moved westward on April 27. Shortly after the sun set at McDonald Observatory in Texas, astronomers there began to observe the optical pulses from the pulsar. In New Mexico, we required that it be dark for the rocket launch, so we could photograph stars from the rocket during the flight to obtain the pointing directions of our instruments — but not too late, or the Crab would be too low in the sky. These conditions were satisfied about 30 minutes after the Texas astronomers could no longer observe the setting Crab. The rocket was launched. The flight was successful and the data were telemetered to the ground. At the end of the five-minute flight, the rocket reentered the atmosphere, and our payload was successfully parachuted to the ground. Then, about 30 minutes later, under clear skies, it became dark enough in California for the observer on the 200-inch to carry out his work.

Transfer of Energy to the Electrons

It was widely accepted by this time that a rotating neutron star existed at the center of the Crab Nebula. As outlined above, such a spinning object can contain an immense amount of rotational kinetic energy — about 10^{49} ergs for a neutron star with a 33-millisecond period. In fact, as we noted, it may have had a one-millisecond period and 10^{52} ergs immediately after the stellar collapse.

The reality of this neutron-star model was confirmed in a dramatic and convincing fashion: radio astronomers discovered, in 1968, that the pulse rate was gradually slowing down. The fractional change of rate per day was only 1.1×10^{-6}, corresponding to a period change of 36×10^{-9} seconds per day. The associated energy loss (for a neutron star's theoretical radius of 10 kilometers and theoretical mass similar to that of the sun) is calculated to be 4×10^{38} ergs per second. This is almost exactly the total electromagnetic energy radiated by the entire Crab Nebula over the entire spectrum. The remarkable agreement cannot be an accident. The rotational kinetic energy of the pulsar, without doubt, is being given up to electrons, which in turn emit the observed radio, optical, and X-ray photons. And since we used the mass and radius of a neutron star in our calculation, the agreement of the two energy rates confirms that the pulsar is indeed a neutron star.

Attention now turned to the question of just how the rotational kinetic energy of a massive, compact star is given to individual electrons. This is the one step in the conversion of energy from gravitational potential energy (before stellar collapse) to the radiant energy of the observed photons that we have not yet discussed. Unfortunately the answer is not yet clear. However, some of the probable features of the spinning star system do shed some light on the problem.

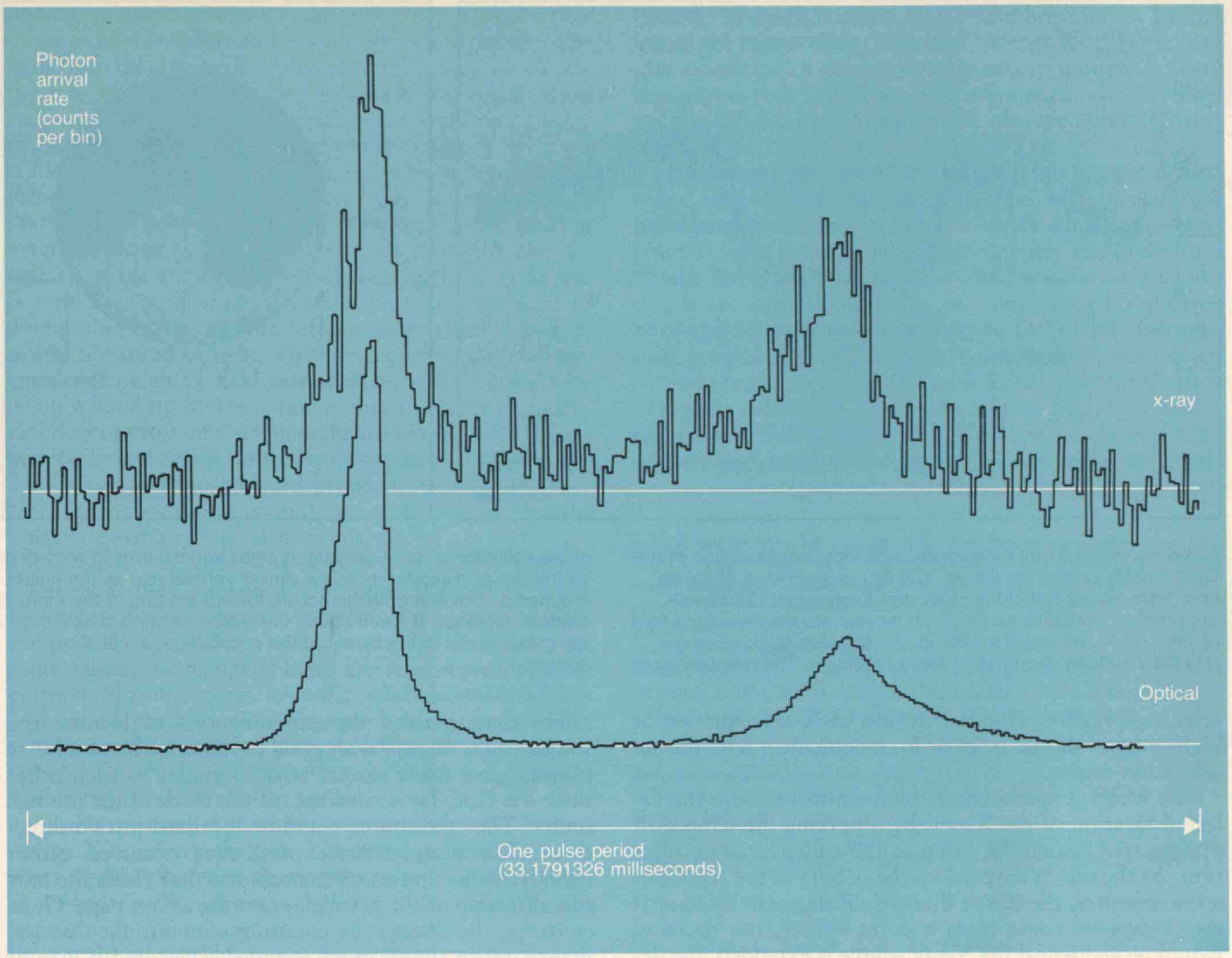
A rapidly spinning neutron star is believed to have a magnetic dipole field similar to that of the earth, but much more intense. In the initial collapse of the star, the magnetic field lines should be carried inward by the infalling, ionized matter. The line density would then increase inversely with the square of the star's radius. By definition, the magnetic field strength increases proportionally with the line density. Thus if the collapse is from a radius of 10^{11} centimeters to one of 10^6 centimeters (a factor of 10^5) the magnetic field strength will increase by a factor of 10^{10}, and an initial field of 100 Gauss would become 10^{12} Gauss. Some estimates place the neutron star's field as high as 10^{15} Gauss. For comparison, the field at the earth's surface is about 0.5 Gauss.

If the magnetic dipole's axis is offset from the spin axis of the neutron star, the magnetic field pattern surrounding the star will wobble. Thus, at any point in space near the pulsar, extremely intense magnetic fields will be oscillating in magnitude and direction — with a 30 Hertz frequency for the Crab's pulsar. One can well imagine that these oscillations could accelerate the electrons.

Most of the energetic electrons must somehow be carried through the nebula for distances of one or more light-years before they emit the observed radio, optical, and X-ray photons. This radiation constitutes the emission from the nebula as a whole, rather than from the pulsar. The entire nebula does not pulse, since an object several light-years across cannot communicate with itself in less than several years. Thus we would not expect it to pulse coherently with millisecond time constants.

Others of the accelerated electrons emit energy in the near vicinity of the pulsar in such a way that this energy does appear pulsed to us. It is likely that the photons are emitted continuously as one or more beams from the neutron star. As the star rotates, the beam rotates with it and sweeps past the earth once each cycle. The sweeping of a lighthouse beam is an appropriate analogy. Like some lighthouses, the Crab pulsar appears from its two pulses per cycle to have two beams.

This pulsing phenomenon must take place very close to the pulsar. The one-millisecond structure of the pulses in-



Arrival rates of photons from the Crab Nebula's pulsar. The top curve shows X-ray data recorded by M.I.T.'s SAS-3 satellite last May 30, and analyzed by F. Primini, F. Li, and S. Rappaport. The data stream has been "folded" into the known period of the pulsing — about 33 milliseconds — and the photons then placed in 256 "bins." Two peaks of X-radiation from the pulsar are seen to rise above the steadier X-radiation from the associated nebula. The bottom curve shows arrival rates for optical photons; the curve has been degraded in resolution to match that of the X-ray curve above it.

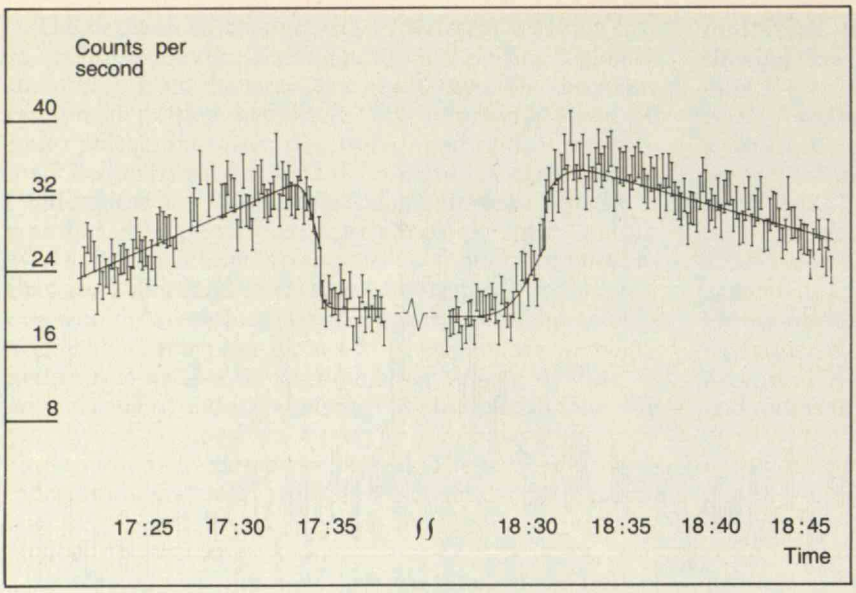
dicates an emission region of 10^{-3} light-seconds (about 300 kilometers) or less. This is smaller than the 1,500-kilometer radius of the "speed-of-light cylinder" — a cylindrical surface around the Crab pulsar which is coaligned with the pulsar's spin axis. An object mounted on this surface would travel at the speed of light if the cylinder were rotating rigidly with the spinning star. A greater speed is impossible, so no object or magnetic field line outside this cylinder can rotate rigidly with the star. Thus we expect that the beaming process must occur at or inside the 1,500-kilometer distance. Some theories hold that the beamed radiation is created at the turbulent conditions which must exist at 1,500 kilometers.

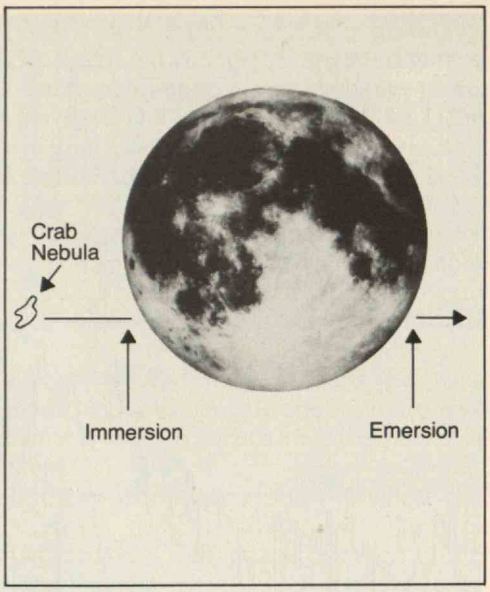
Locating the Energetic Electrons

The electrons that move into the nebula may not have their full energy when they leave the vicinity of the pulsar. It may be that the 30-Hertz oscillating electromagnetic radiation emitted by the pulsar gives up its energy to the electrons at some distance from the pulsar.

The possibility that such a phenomenon is occurring is suggested by the relatively short emitting lifetime (one to two years) of the electrons that produce X-rays and the relatively large extent of the X-ray emission. We know that X-rays come from a large region of the nebula, at distances on the order of one light-year from the pulsar. Thus an electron that emits X-rays would barely make it to the distant region even if it traveled in a straight line at nearly the speed of light. In fact, it probably would have given up a large fraction of its original energy to synchrotron radiation at positions closer to the pulsar. If it were accelerated at some distance from the pulsar, this would be less of a problem. A recent balloon observation by Walter Lewin, George Ricker, and Anton Scheepmaker of M.I.T. has given substantial insight into this matter.

The objective of the balloon experiment was to find the region in the nebula that emits relatively high-energy X-rays — more than 20 keV per photon. (Most of the work discussed earlier pertained to the lower-energy X-ray region, one to 10 keV.) The high-energy X-rays will arise from even higher-energy electrons than is the case for the one-to-10-keV X-rays, and will have shorter lifetimes (a few months) for the emission of X-rays by the synchrotron process. During this interval, the electron cannot travel more than a few light-months from the ac-





A balloon-borne X-ray detector records the disappearance of the Crab Nebula behind the moon, and its reappearance about an hour later. At the left of the chart, the X-ray count (35-82 keV per photon) increases as the Crab moves into the detector's field of view. Then the moon's limb occults the nebula, producing a relatively sudden decrease in X-ray detection. The reappearance of the radiation is more gradual. A small vertical drop is recorded as the pulsar disappears, and a similar vertical rise as the pulsar reappears. The first of these occurs toward the end of the more gradual decrease in X-ray count; this indicates immediately that the pulsar is not in the center of the nebula's region of X-ray emission.

celeration region. Thus the region of X-ray emission at high energies should be close to or coincident with the acceleration region.

The M.I.T. experimenters planned to measure the celestial location of the X-rays by observing the Crab as it disappeared behind the moon in a so-called lunar occultation. As the moon covered up the nebula in the course of a few minutes, the X-ray flux would decrease to zero. If the X-rays all come from a point source, the decrease would be sudden; if the X-ray source is extended, the decrease would be gradual. Thus the moon could provide the X-ray astronomer with high angular resolution. Careful planning was necessary so as not to miss one of the rare lunar occultation opportunities.

The balloon was flown from Saskatchewan, Canada in order to take advantage of the August 13, 1974 lunar occultation of the Crab. The helium-filled balloon was launched early in the morning. By the time it reached its full altitude of 40 kilometers about three hours later, the helium had expanded the balloon to its full diameter of about 100 meters. The X-ray detector was commanded to point directly at the location in the sky where the occultation was to take place at 11:35 AM. The Crab was not initially in the 6° × 6° field of view, but gradually moved into it as the stars rotated relative to the earth. The counting rate gradually increased. Then the edge of the moon quickly occulted the Crab and the X-ray flux disappeared.

The detectors were then pointed toward the location where the Crab would reappear at 12:30 PM. Again the observation was a success. The counting rate suddenly rose as the Crab was uncovered, and then the rate slowly decreased as the Crab left the field of view. Later, as the balloon was passing near one of the northernmost roads in the adjoining province of Alberta, the payload was released from the balloon by telemetered command, the parachute automatically deployed, and the detection system floated safely to the ground where it was recovered and eventually returned to M.I.T.

The data enabled the experimenters to localize the source of the X-rays with good precision. The two lunar transits gave scans almost at right angles to each other since the Crab lay somewhat off the track of the moon's center. Thus the source could be localized in two directions. The disappearance of X-rays occurred rather quickly, indicating a rather small size that yields the narrow direction of the parallelogram shown on page 39. In contrast, the change in counting rate for the X-rays' reappearance shows more rounded edges and a greater total duration. This indicates a larger size in this direction. A small vertical step was observed in each set of data. These indicate the times at which the limb of the moon covered and later uncovered the point-like pulsar source. In the former data it occurs at the end of the decrease in counting rate. This tells us directly that the pulsar is not in the center of the nebular X-ray emission.

A Shock at the Wisps

The balloon observations show that about 70 per cent of the X-ray emission comes from an elongated nebular source of size 25 × 50 arc-seconds (0.6 × 1.2 light-years), that this source is not centered on the pulsar, and that the pulsar emits an observable but not overwhelming portion of the radiation. Moreover, the long direction of the X-ray source lies at right angles to the long direction of the optical nebula. As noted above, the X-ray emission region may well be nearly coincident with the electron acceleration region. Now the lunar occultation experiment tells us that the emission region is centered northwest of the pulsar at a distance of 10 arc-seconds, or about three light-months, from it. Thus it indeed appears that electron acceleration, at least in part, takes place at some distance from the source of energy, the pulsar. Lunar occultation measurements made by other groups are consistent with this finding.

The region just northwest of the pulsar has long been noted to exhibit unusual activity at optical wavelengths. There are several optical wisps within it. Comparison of

photographic plates taken at different times indicates that they can move slightly and can occasionally brighten. The light from these wisps is highly polarized; they are clearly the site of high-energy electrons emitting synchrotron radiation. It appears that the pulsar is transferring energy to electrons at the site of these visible wisps.

Models for this energy transfer have been developed at Princeton University and elsewhere. The general picture is that charged particles can be accelerated by the moving magnetic fields to enormous energies as they leave the surface of the rotating pulsar. These particles move out beyond the speed-of-light cylinder into the nebula. In so doing, they form a wind of particles which travel at nearly the speed of light. This wind carries a wound-up, spiral-like magnetic field with it. (The field is continually being wound up by the spinning pulsar.) Since the particles do not cross the magnetic field lines, they no longer accelerate and hence do not emit synchrotron radiation. This wind, and the outward propagating 30-Hertz electromagnetic radiation, would sweep the region near the pulsar free of any high-density plasma.

Eventually, this fast, low-density wind would impinge upon the denser, slower-moving nebular magnetic fields and gas — the debris of the supernova explosion. At this point, a shock develops wherein particle directions are randomized, the magnetic fields are compressed, and the entire outflowing energy from the pulsar is converted into high-speed particles. The electrons then begin to emit synchrotron radiation as they travel farther out into the nebula. The theory indicates that the wisps would be the visible ramification of the shocks.

In this picture, we might expect to see the highest energy X-rays from the region of the wisps. In fact, that is what we find. We even see that the elongated X-ray emission region is aligned with the visible wisps. These results appear to confirm that electron acceleration takes place at or near the wisps. This forms the final link in the chain of energy that began with the gravitational potential energy of a dying star and ends with the energy of the photons that travel 5,000 light-years to our detectors at the earth.

The Power of the Crab

We have shown that the enormous emission of radiant energy from the Crab Nebula derives from the gravitational potential energy which was released in a sudden stellar collapse observed 921 years ago. We saw that this energy was stored as rotational kinetic energy in a rapidly spinning, very compact neutron star and that this energy is being slowly lost to very energetic electrons. The electrons appear to receive their energy, at least in part, at a shock front a few light-months from the pulsar. They then travel out into the nebula to distances of a few light-years, losing energy by the synchrotron process to radio, infrared, visible, ultraviolet, X-ray, and gamma ray photons, some of which reach the earth.

The Crab Nebula's very existence at its present brilliance depends, year by year, upon the existence of the tiny pulsar at its center. The ratio of diameters (nebula to pulsar) is about 10^{12}. This contrast in sizes of two closely interacting objects is remarkable. The ratio of the diameter of the solar system (out to Pluto) to the diameter of the sun is only about 10^4, and the ratio of the diameter of the observable universe to that of our Milky Way Galaxy is only about 10^5. True, the diameter of the Galaxy compared to that of our sun is also about 10^{12}, but the sun is only one unimportant star among 10^{11} stars in the Galaxy. The pulsar drives its surroundings simply by virtue of the tremendous "flywheel" energy it contains. The rate of release of this energy by a very modest slowing down (one part in 10^6 per day) amounts to the 10^{38} ergs per second required to explain the observed photon emission.

Our present understanding of the Crab has permeated other areas of astrophysics. Galaxies and quasars are postulated to contain massive rotators which would explain some of their observable properties. The quest for a "black hole" and the possible identification of a candidate in the constellation Cygnus is encouraged (rightly or wrongly) by the knowledge that the last exotic, theoretically predicted compact object — the neutron star — was actually found in the Crab Nebula. The continued study of the physics taking place in the nearby Crab Laboratory will certainly continue to give us insight into phenomena occurring at much less accessible places in the universe.

Hale Bradt received his A.B. in music from Princeton University and his Ph.D. in physics from M.I.T., where he remained as an instructor, and is now Professor of Physics and a member of the Center for Space Research. Professor Bradt has been active in M.I.T.'s X-ray astronomy group since 1966. He is Associate Editor of the *Astrophysical Journal Letters* and Secretary-Treasurer of the High-Energy Astrophysics Division of the American Astronomical Society. This article was written in moments caught during the preparation, launch, and orbiting life of the SAS-3 satellite, on which Professor Bradt is co-investigator.

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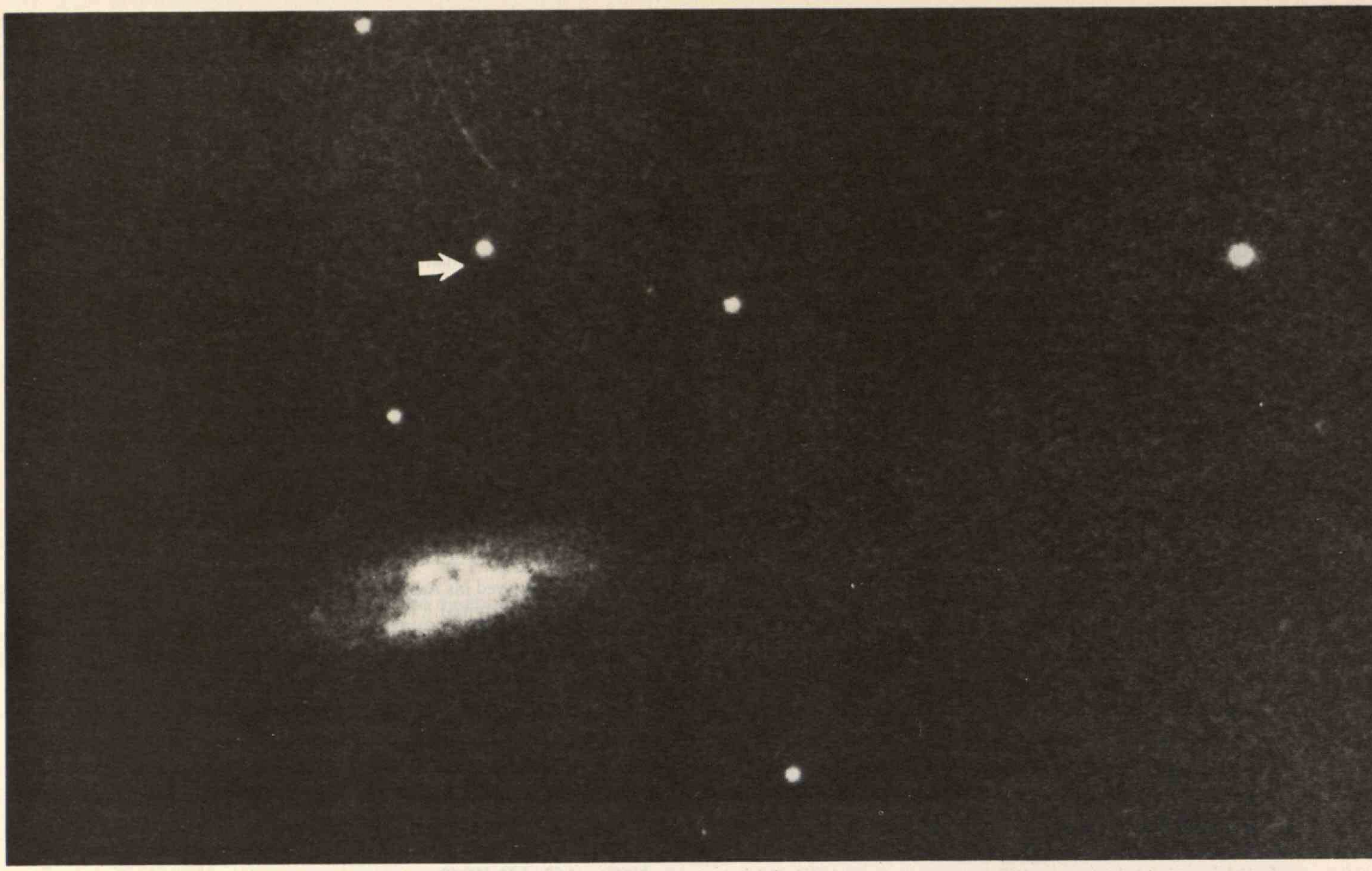

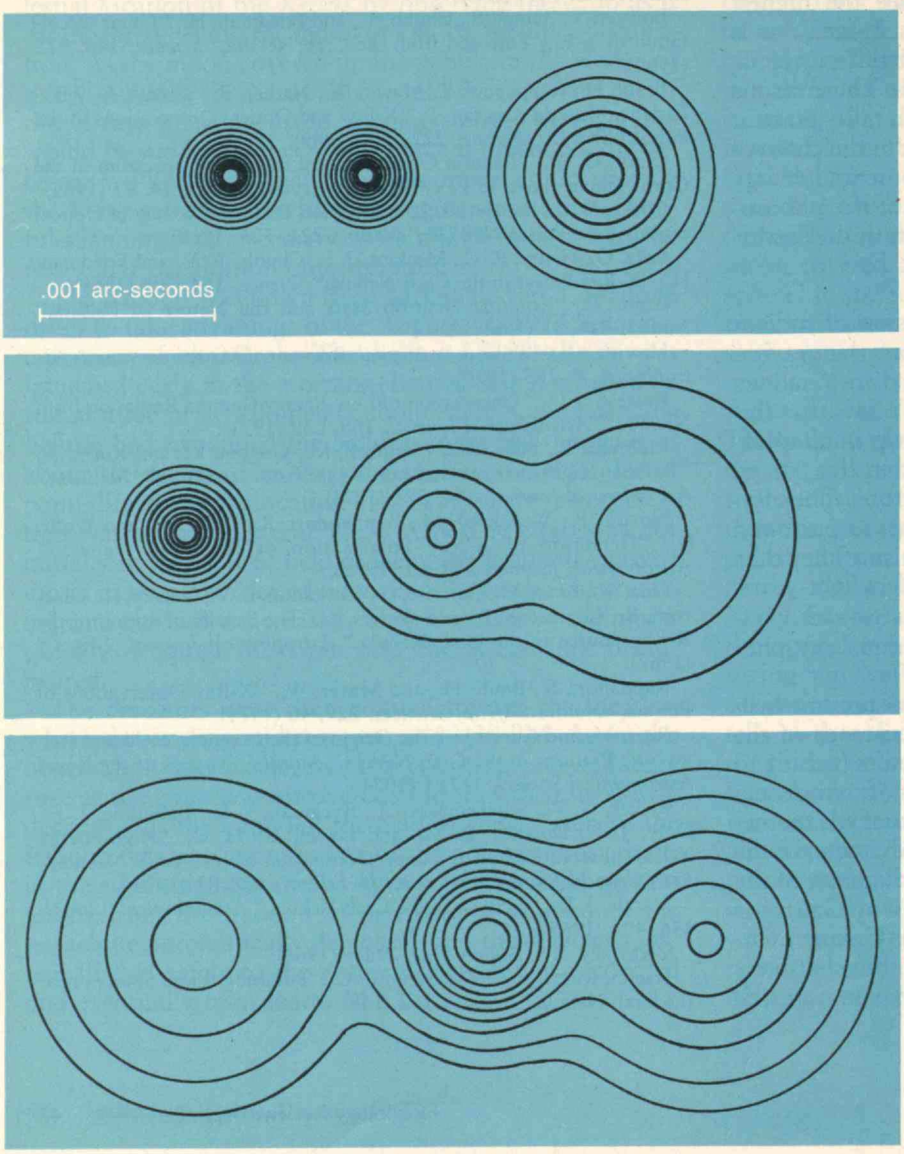
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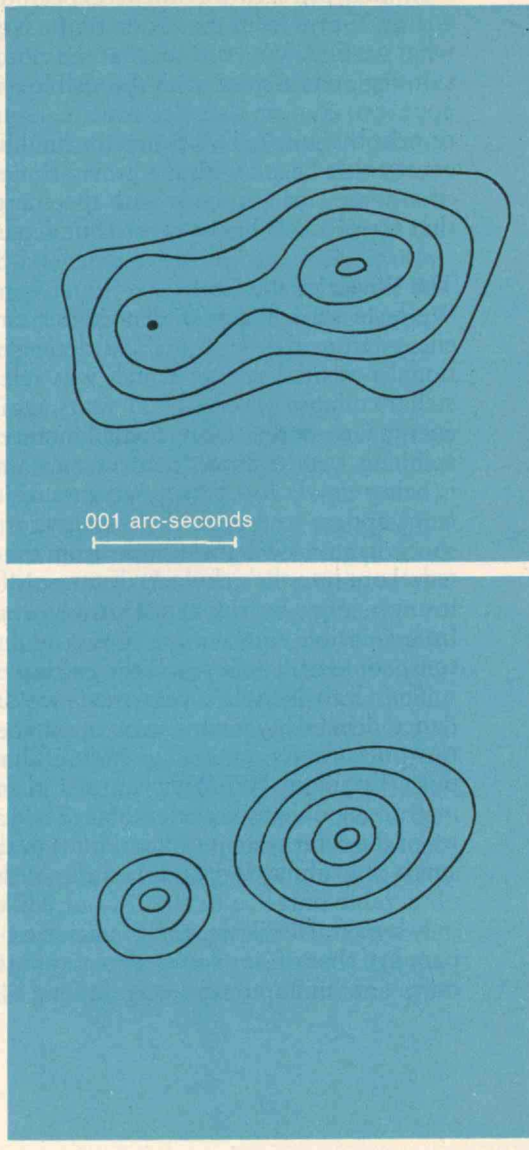
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Networks of radio telescopes thousands of miles apart are producing the first maps of quasars and the regions where stars form.

Bernard F. Burke
Professor of Physics
M.I.T.

Radio Pictures of the Sky

A crucial difference between astrophysics and laboratory physics has its roots in the vast distances that separate astrophysicists from the objects they study. The laboratory physicist can push and poke nature, and even create substances nature has never known. The astrophysicist, on the other hand, must be content with the particles and photons nature chooses to provide: the sky appears as a screen on which the universe is projected, and the properties and distances of celestial objects must be inferred from very subtle effects. When the twentieth century began, virtually our only knowledge about the stars was their approximate distance. We did not know why they shone, or where we were in their midst. Cosmology as a science instead of a philosopher's game lay decades in the future. The marvelous blooming of knowledge began only when the tools and knowledge of the physicist were applied intensively to astronomical problems: first the optical spectroscope, then radio and electronic technology, and finally the use of giant rockets to loft X-ray telescopes above the atmosphere. Cosmology is now a real observational science — the expanding universe is a fact to be explained. We know of pulsars, quasars, X-ray stars, and radio galaxies; and we know that the space between the stars is far from empty.

The more fundamental the knowledge, however, the more reluctant nature often is to reveal it. The most mysterious objects are often so faint that there are too few photons to yield a good image, and even when the object is bright enough to see easily, its details are always blurred by the imperfect angular resolution of our instruments. The photograph at the left is an example; it shows a quasar next to a galaxy. While the galaxy is not especially distant — only 100 million light-years or so — it is too far away for individual stars to be seen, and it therefore registers on the photographic plate as a fuzzy patch with a few bright knots, the fuzzy light coming from its 10 billion stars, while the bright knots may be regions where new stars are forming. The quasar is the real object of interest in this photograph, but it looks exactly like the stars that happen to lie in the field of view. When the composition of the quasar's light is studied by the spectroscope, however, its characteristic spectral lines are found to be shifted toward the red end of the spectrum by a large amount, implying that the quasar is rushing away from us at a third the speed of light — nearly a hundred times faster than the photograph's galaxy! This, in fact, is the characteristic feature of quasars: they look like stars but are receding at tremendous velocities. The Hubble law — that the more distant a galaxy is, the more rapidly it appears to be receding — is the only way of measuring the distances to faint galaxies. If quasars obey the same law, they must be extraordinarily distant and extraordinarily luminous. They might consequently form an ideal class of objects to help astrophysicists probe the outermost reaches of space.

Unfortunately, there is not complete agreement that quasars do obey the Hubble law. We still do not know what they are, or what tremendous source of energy keeps them so bright. We do know that they flicker, both at radio and optical wavelengths, and their characteristic flickering times can be used to estimate their sizes, since an object generally cannot flicker in less time than it takes light to cross it. The size turns out to be one light-month to perhaps a light-year — large by our earthbound standards but small on a galactic scale. A quasar's details could be seen only after a thousandfold improvement in the angular resolving power of our best telescopes.

Top photograph: Galaxy NGC 3067 and quasar 3C232, as seen through an optical telescope. The galaxy, an irregular spiral, is about 100 million light-years from earth. The quasar (indicated by the arrow) is more mysterious: its shifted spectral lines lead to the conclusion that it is extraordinarily distant — billions of light-years away. The quasar's appearance, however, is quite prosaic: observed through an optical telescope, it looks no different than the point of light directly above NGC 3067, which is judged to be a young star in our own galaxy.

Bottom left: The structure of 3C273, the brightest quasar in the sky. Observations made on a network of three radio telescopes were used to create three models — possible maps — consistent with the data. Contour lines are drawn at increments of 10 per cent of maximum brightness, with an additional outermost contour at one-twentieth of maximum. The models are taken from recent work by R. T. Schilizzi and colleagues at Cal Tech.

Bottom right: The structure of quasar 3C345. Data recorded by four radio telescopes was mathematically transformed into a map of the object, shown in the upper of the two drawings; the map is taken from a recent Ph.D. thesis by J. R. Wittels at M.I.T. The lower drawing is a model consistent with the data. In each of these illustrations, contour lines are drawn at 5, 25, 50, 75, and 95 per cent of maximum brightness. About 0.0015 arc-seconds separate the centers of the two structures in the model; by comparison, the quasar in the photograph at the top of the page is a spot of light one arc-second across, and utterly without detail.

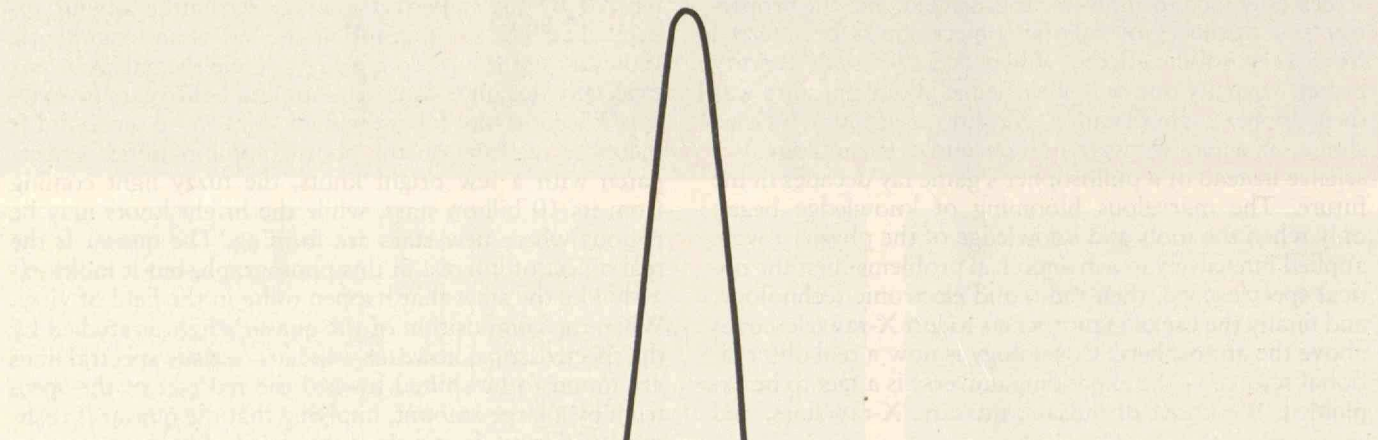
The Michelson Interferometer

Optical telescopes can seldom produce pictures with angular resolution better than one second of arc because of

our being situated beneath the earth's atmosphere — healthy for us but unhealthy for telescopes. The incoming starlight is randomly refracted as it passes through atmospheric irregularities, thus blurring the image slightly, much as looking through a wavy window pane would. When the "seeing," as astronomers call it, is bad, the resolution can be degraded to five or 10 arc-seconds, but even in the very best locations on earth, the seeing image of a star is seldom smaller than half an arc-second. This is not good enough to resolve the disc of any star, let alone the details of quasars.

There is still another limitation to a telescope's performance, one that is keenly felt by radio astronomers. Whenever a wave-like signal is sent through an aperture, it spreads into a definite angle. The phenomenon is known as diffraction, and it limits the performance of microscopes and cameras as well as radio telescopes. Its special importance for the radio astronomer stems from the fact that the size of the aperture *in wavelengths* determines the angle of diffraction — the smaller the aperture, measured in wavelengths of the incoming radiation, the larger the spreading angle. Green light has a wavelength of about one fifty-thousandth of an inch; for a typical camera aperture of one-tenth inch, this gives a diffraction spot of about half a minute of arc. Only by widening the lens aperture until the imperfections of the lens limit the camera's performance can the angular details of the picture be improved.

The unfortunate radio astronomer, however, must contend with signals that are anywhere from a centimeter to many meters in wavelength, and the great radio telescopes of the world, large as they are, fare poorly in the angular resolution of such input. Two large instruments that have been frequently used by the M.I.T. radio astronomy group are the radome-enclosed 120-foot Haystack telescope in Westford, Massachusetts, and the 140-foot telescope of the National Radio Astronomy Observatory in Green Bank, West Virginia. Both perform well at about one centimeter wavelength, where their angular resolution is one minute of arc — about the same as that of the unaided human eyes. The illustration at the right shows the consequences — the great Andromeda Nebula (our giant neighbor galaxy), as it appears in instruments with 12-minute, one-minute, and one-second resolution. The radio astronomer using these instruments can never get an image of the Andromeda Nebula any sharper than the one-minute version, and the details can be much fuzzier. Nature, for instance, provides radiation from hydrogen



The generation of a narrow spike is used to illustrate a branch of mathematics developed by Joseph Fourier. The idea is that virtually any mathematical curve can be constructed by adding sine waves of various frequency, appropriately scaled in height. In the illustration, the waves tend to cancel outside the center as two, then four, and then eight of them are combined. The spike grows narrower and taller; finally, at the limit of an infinite number of superposed frequencies, it would be infinitely high and infinitely narrow. The mathematical technique is known as Fourier analysis.

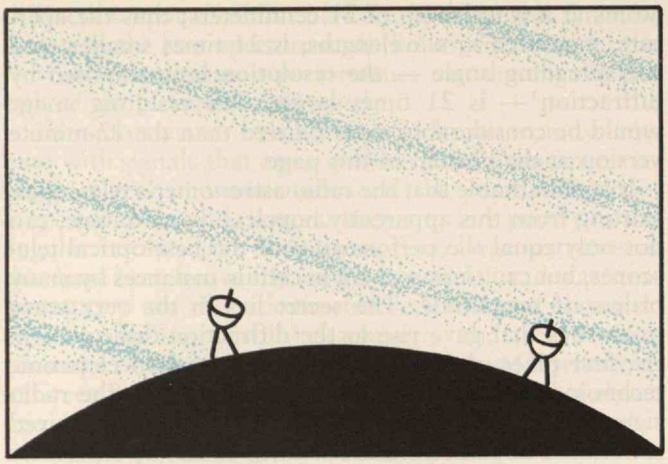
atoms at a wavelength of 21 centimeters; thus the aperture, measured in wavelengths, is 21 times smaller, and the spreading angle — the resolution limit imposed by diffraction — is 21 times larger. The resulting image would be considerably more blurred than the 12-minute version at the bottom of this page.

It is remarkable that the radio astronomer's telescopes, starting from this apparently hopeless disadvantage, can not only equal the performance of the best optical telescopes, but can surpass them in certain instances by many orders of magnitude. The secret lies in the very wave properties that gave rise to the diffraction difficulties in the first place. At radio frequencies, modern electronic technology allows the observer to manipulate the radio signals with great precision. The radio signals received simultaneously at two radio telescopes can be separately amplified, and the two signals sent to a central location where they can be compared, vibration for vibration. The figure on page 48 illustrates such a comparison system, with two radio telescopes each receiving an oscillating signal from a radio "star" — a point source — after which the two signals are added together. The added signal depends on the relative phases of the incoming signals: if the two are synchronous, they will add together, but if they are 180° out of phase, one going positive as the other goes negative, they will cancel, and there will be no output. For the diagram, it is assumed that the cables bringing the signals to the adder are equal and absolutely stable in length, and so the output depends entirely on the path difference — the difference in length between the ray paths from the star to the telescopes. If the path difference steadily changes, then the two signals will alternatively reinforce and cancel one another, and a sinusoidally varying output will be obtained.

A device such as that shown on page 48 is known as a Michelson interferometer, named after the great American physicist who invented it to study the angular diameters of stars. Michelson's optical version had no amplifiers, of course, and a system of mirrors had to be used to bring the two light beams to a common point, where they "interfered." (The term "interference" refers to the addition process, in which the signals tend to either reinforce or cancel one another.) In the radio version, with two radio telescopes fixed to the surface of the earth, the apparent direction of a celestial radio source changes as the earth rotates. This varies the path difference throughout the day. At the instant the star is straight overhead, the path lengths are equal for any wavelength, and the signals add. But before and after the star passes overhead, the path lengths differ, and the interferometer's output oscillates in a manner determined by the spacing between the antennas, measured *in wavelengths*.

The discussion so far assumes a point source. Now we inquire what happens if the source being observed has a finite extent and detailed structure. If, as in the illustration on page 49, the radiation emanates from two point sources, the interference will again be constructive when the double source is overhead, but there will come a time, for example, when the signals from one point are interfering constructively while the signals from the other are interfering destructively, and one pair will cancel the other. The output during the day therefore exhibits a more complicated behavior than the output for a point source. The output is called interference fringes, and for the double source the fringes are themselves modulated sinusoidally.

The Andromeda Galaxy, shown with progressively poorer angular resolution. One arc-second resolution (top photograph) is typical of the best optical telescopes. One arc-minute resolution (middle) is typical of a radio telescope receiving at a wavelength of one centimeter. Twelve arc-minute resolution (bottom) would result from use of a somewhat longer wavelength.



The principle of interferometry is demonstrated for star-like radio sources so distant that their radiation arrives at the earth as a plane wave — that is, as sheets of crests and troughs. In the leftmost drawing, the earth's rotation has brought two radio telescopes to positions where the signals they record are in phase: at the instant shown in the drawing, both telescopes are receiving a crest of the source's radiation. At some later time, as shown by the second drawing, the earth's rotation carries the instruments to positions where the signals they record are 180° out of phase — one telescope detects a peak when the other detects a trough, and

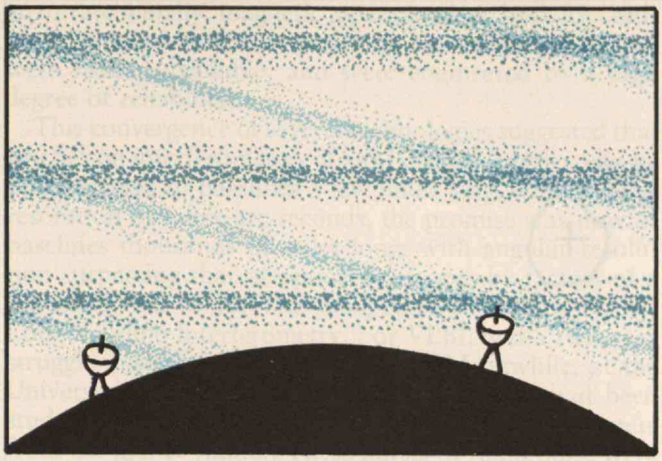
Transforms of the Sky

The essential problem in interferometry is to determine the map of a source, given its interference fringes. It turns out that the brightness distribution of a source is related to the interferometer's fringe output by a mathematical operation known as the Fourier transform. One of the most elegant fields of mathematics, the Fourier transform and its simpler relative, the Fourier series, were developed by Joseph Fourier in the early nineteenth century in the course of work leading to his great essay, *The Mathematical Theory of Heat.* The core of his idea was that any reasonable mathematical expression can be represented by superposing an infinite series of sine waves of varying wavelength. The idea is illustrated on page 46, where an infinitely narrow spike is generated by the successive addition of sine waves of shorter and shorter wavelength. At the origin, where all the waves are simultaneously in phase, they all add to give a high value. Outside the center, some are positive, some negative, and their total is much less. As one approaches the limit of all possible wavelengths, the cancellation becomes perfect everywhere except at the origin, where the spike becomes infinite. More complicated wave forms than an infinite spike can be created by choosing the proper amplitudes for sine curves of different wavelengths.

When Fourier first formulated the method, the great French mathematicians Laplace and Lagrange were scandalized by its lack of rigor. Perhaps they were justified, because over a hundred years were needed to put the theory into a form that would please the mathematicians. M.I.T.'s Professor Norbert Wiener, about whom many legends (most of them true) are told, was one of the mathematicians who finally placated the ghosts of Laplace and Lagrange with a properly rigorous treatment of the subject. Professor Wiener played another, essentially non-mathematical, role in the history of Fourier theory: he was one of a small band of thinkers who realized that the Fourier transform could be applied to a vast array of problems; beside the classical ones of vibrating strings, sound waves, electrical circuit design, and heat conduction, there was also a host of new ones in antenna theory, communication and information theory, servomechanisms, and even pure mathematics. In a sense, there are two alternative worlds: the "real" world, described by the variation of a real quantity, and the Fourier world, in which frequencies or wavelengths can be used without loss of descriptive accuracy. This second world is not completely foreign to our understanding. Sound waves come to us as a pressure that fluctuates in time, but we know that sound can also be described by its frequency content. A "voice print" is the frequency distribution of a person's speech — it is in truth the Fourier-transformed voice.

Perhaps the simplest way to look at the Fourier transform is to regard it as the spectrum of a phenomenon. The spectrum of a sharp click (the spike shown on page 46) is a mixture of sine waves including all frequencies, with all the waves set at equal amplitude — a "flat" spectrum — and with all the waves in phase at the instant of the click. A collection of many sharp pulses also has a flat spectrum, but now the phases turn out to be random. Such a chaotic mixture is called white noise, and is approximated very well in the audio spectrum by uttering sibilant *sh*. A radio turned up to full gain with no station broadcasting gives this familiar hissing sound; what the listener hears is either the random noise of the radio's electrical components or the noise of the universe, depending upon the quality of the radio and the region of the spectrum to which the radio is tuned. Many good television sets, when set to Channel 2 while no station is broadcasting, are actually picking up radio noise generated in the far reaches of our galaxy by cosmic-ray electrons.

Radio astronomers, as they began to use Michelson interferometers for their observations, very soon became aware that they were in actuality taking the Fourier transform of the sky. The time-varying output of the interferometer was a sine curve of definite frequency, with the frequency determined by the antenna spacing. By moving their antennas to different spacings, or by using several antennas, outputs at various fringe frequencies were obtained. Thus they were able to build up the Fourier transform of many bright radio sources, including the celebrated supernova remnant of 1054 A.D. that we call the Crab Nebula. After the interference fringes had been found for a number of spacings, the mathematical transformation could be performed easily, and crude maps were obtained. The full power of the method, however,



if the two signals were added they would cancel. The third and fourth drawings show the consequences for an interferometer if the radio source is somewhat more complicated. Here, it consists of two points in the sky, from each of which plane waves arrive at the earth. In the third drawing, one source's pair of signals (light color) interfere constructively while the other pair (dark color) interfere destructively. In the fourth, both pair interfere destructively. As these drawings suggest, the interference pattern created by the earth's rotation is more complicated for this more complicated source.

was not exploited until Professor Martin Ryle of the Cavendish Laboratory realized a simple truth: as the earth rotates, antennas on its surface move through space with consequences that are illustrated in simple form on page 53. The mathematics for an interferometer shows that the crucial parameter is the device's effective spacing — the projection, on a plane perpendicular to the line of sight, of the distance separating the two antennas. When a radio source appears on the horizon, and the interferometer is almost end-on, the effective spacing is a very small number of wavelengths; in Fourier language, the spatial frequency is very low. As the source rises in the sky, the projected spacing grows larger until the source is straight overhead and the spacing is the largest possible number of wavelengths. At the same time, the baseline orientation has been changing, and so one has obtained many values of the Fourier transform. Deriving a sky picture is a two-dimensional problem — the fringe frequencies resulting from the east-west and from the north-south antenna spacings are independent quantities. The mathematics is more complicated, but the principles are the same. With a variety of interferometer spacings, one gradually obtains the complete Fourier transform, and the result is a complete "picture" of the source, but in its Fourier-transformed, or "voice-print" form. The final, "true" picture of the source can then be generated by a computer.

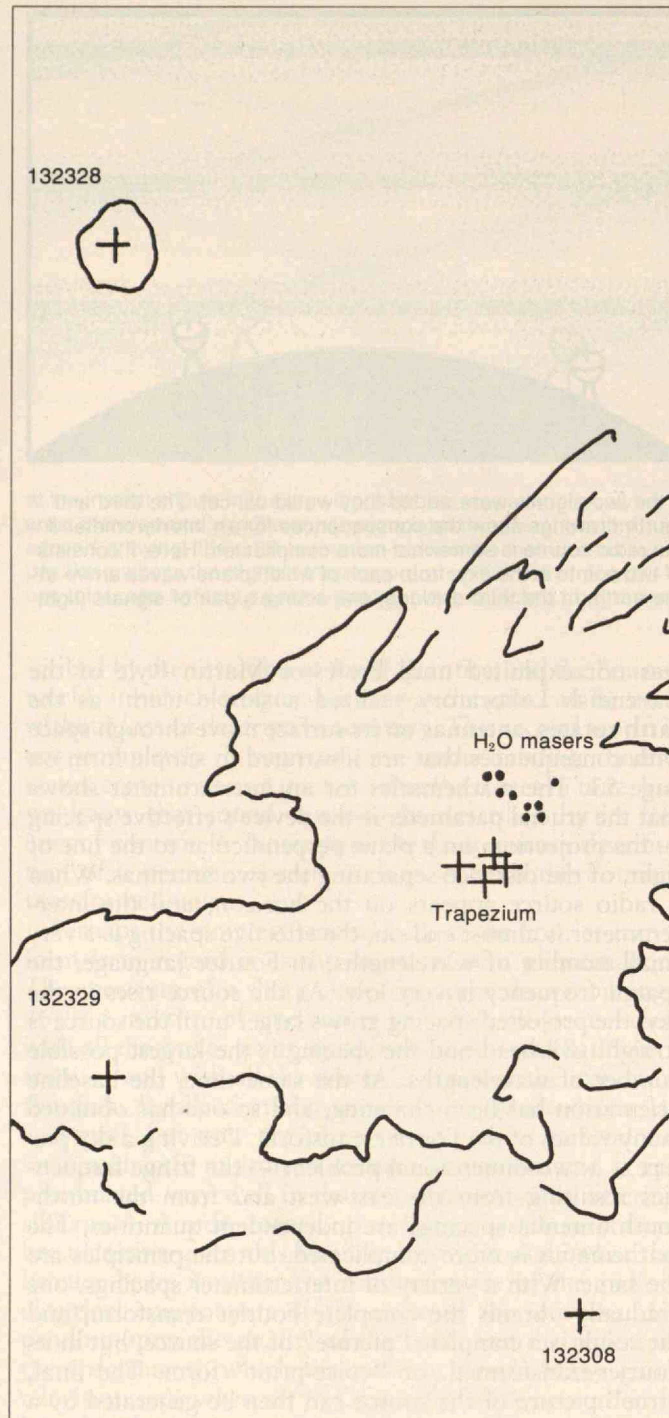
The technique, start to finish, is known as aperture synthesis, since one is, effectively, building up a radio antenna aperture that is as large as the interferometer spacing. The first aperture synthesis project at the Cavendish produced the equivalent of an aperture one mile wide. No single radio telescope comes close to achieving such dimensions; the very largest single dish, the 1,000-foot instrument operated by Cornell University in Arecibo, Puerto Rico, has less than one-fifth the angular resolution at any given wavelength.

One of the most powerful instruments of the aperture-synthesizing variety is now operating in the Netherlands, where 12 antennas are ranged along an east-west line 1,600 meters in length. At the wavelength of the 21-centimeter hydrogen line, 23 arc-second angular resolution is achieved. An even more powerful instrument of this class is now under construction in the United States, and is known as the VLA — the Very Large Antenna. Twenty-seven antennas, each 88 feet in diameter, will be deployed on a Y-shaped set of railroad tracks stretching over an area 15 miles in diameter on the Magdalena flats, a hundred miles southwest of Albuquerque, New Mexico. The VLA's angular resolution will be better than one second of arc — it will produce views of the radio sky every bit as detailed as those of the optical astronomer.

Very-Long-Baseline Interferometers

The full power of the Michelson interferometer as a tool of radio astronomy was only partly realized by aperture synthesis, which still required that the radio signals be brought together by means of cables from the various antennas. The next step was conceived simultaneously by at least three groups of radio astronomers, one in the U.S., one in Canada, and one in the Soviet Union. The Soviet group could find no financial support, so the idea languished there, but the American group, based at Cornell and at the National Radio Astronomy Observatory, and the Canadian group, based at the National Research Council, the University of Toronto, and the Penticton Radio Observatory, both began active work in 1965.

The core of the idea is that radio waves, after being amplified, need not be directly combined by cables as suggested by the illustrations above, but can be recorded, on magnetic tape, for instance, and the recombination of signals can be effected later. There is one fundamental problem, however — the signals must be recorded with great timing accuracy. If one signal slips in time by as little as half a wavelength with respect to the other, the two signals will cancel instead of add — destructive interference will occur instead of constructive interference. The incoming signals typically have frequencies of 10^9 to 10^{10} Hertz (cycles per second), so the recording process must have better than one part in 10^{10} accuracy for even a one-second observation. Fortunately, technological advances had made such accuracy a realistic goal. Atomic frequency standards, with accuracy several orders of magnitude better than the minimum requirement, were commercially available, so time-keeping was no longer a barrier to the scheme. Moreover, solid-state digital electronics had reached a stage of development that allowed the signals to be handled in digital form, with a very low



H_2O masers in the Orion Nebula. At the left, the nebula is shown in a photograph taken with the 200-inch telescope at the Hale Observatories. Invisible in this image, but shown in the drawing at the right, is the Trapezium, a group of four very young stars. Near the Trapezium is a compact group of masers, apparently comparable in size to the stars. H_2O masers appear to occur in regions of glowing hydrogen gas that is kept in an excited state by the light from young stars.

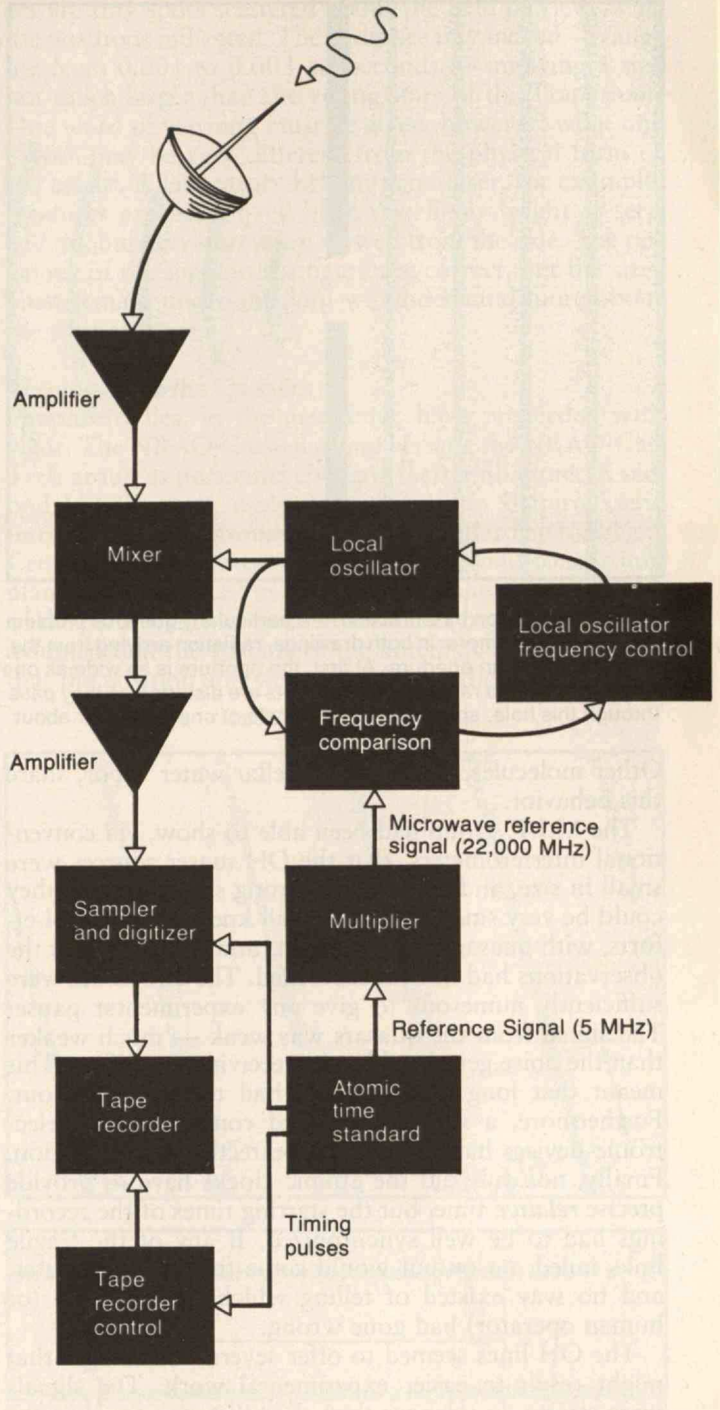
error rate. Finally, magnetic tape recorders, both for computer systems and for recording television programs, were readily available, and were engineered to a high degree of reliability.

This convergence of several technologies suggested that Michelson interferometers of any baseline length could be built; instead of baselines a few miles long, with angular resolution of a few arc-seconds, the promise was now of baselines thousands of miles long, with angular resolution surpassing that of optical telescopes by factors of a thousand and more! The prospect was dubbed "Very-Long-Baseline Interferometry," or VLBI, and a two-year struggle ensued to make it a reality. Meanwhile, at the University of Florida at Gainesville, a group had been studying radio emissions at wavelengths of tens of meters from the planet Jupiter. These bursts of radio noise were known to be coming from well-localized regions of the planet, and the relatively low frequency (10^7 Hertz or so) coupled with the intensity of the bursts offered the hope of pursuing VLBI with ordinary crystal oscillators as time standards, and with ordinary, hi-fi tape recorders.

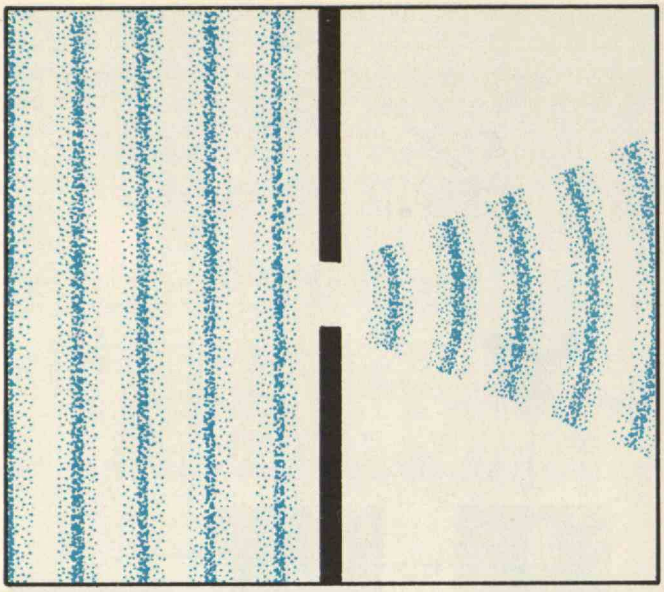
Astrophysical Masers

At the same time, our group at M.I.T. had been studying an entirely different celestial phenomenon, using conventional Michelson interferometers. The unstable hydroxyl radical (OH) has a set of characteristic radio lines with wavelengths near 18 centimeters; these lines were first detected from the sky at the Millstone Field Station of Lincoln Laboratory by a combined M.I.T.-Lincoln Laboratory team. As research proceeded, anomalies appeared: the relative intensities within the set of OH lines were in wild disagreement with theoretical predictions, and the OH lines were often strongly polarized. This strange behavior prompted one group to suggest that the lines were not coming from OH at all, but from a new compound they called "mysterium." Events have proven that the lines are indeed from OH; even in 1967 the indications were strong that we were observing a naturally occurring maser phenomenon — hitherto known only in the laboratory.

"Maser" is an acronym, taken from the words *M*icrowave *A*mplification by *S*timulated *E*mission of *R*adiation. The phenomenon can occur when an anomalous population of energy levels is induced in an appropriate material. Normally, the higher the energy level available to any atomic or molecular system, the smaller the number of atoms or molecules to be found in that state. Accordingly, when radiation passes through matter in the normal state, it is attenuated, since whenever a photon induces a transition from a lower to an upper level, it is absorbed in the process. The reverse procedure — stimulated emission, with the photons causing downward energy transitions and creating more photons in the process — occurs with equal probability, but since more atoms or molecules are in the lower levels, absorption predominates. In a maser, an inversion of the population is induced by outside means, and when an electromagnetic wave that matches the energy difference between two levels passes through, it is amplified rather than attenuated. The notion that nature has from the beginning known how to build such amplifiers was at first a strange one, but it now appears that the OH maser phenomenon frequently occurs in regions of space where tremendous quantities of infrared and ultraviolet radiation are present. Regions of star formation are a favorite location.



A block diagram of the electronics and recording equipment that enable a radio telescope to become part of an interferometer with a baseline thousands of miles long. The signals detected by the radio telescope are at too high a frequency to be recorded directly. Instead, a superheterodyne system must be employed: An atomic time standard provides a reference signal that is typically 5 megaHertz in frequency. This reference, after multiplication to microwave frequency, enters the loop at the upper right of the diagram, and serves to drive precisely a local oscillator. The *difference* between the oscillator's output and the signal detected by the radio telescope is a signal with a very low frequency; it appears at the "mixer" output, and can be amplified and recorded by conventional means. The diagram follows the system employed by researchers in the U.S.: the atomic time standard generates timing pulses to "chop" the signal, which is then converted to digital form and recorded. In a commonly used setup, two thousand feet of recording tape are required for every three and a half minutes of data. The signals from *two* radio telescopes simultaneously observing the same object must be recorded in this way. At a later time, a computer will generate interference patterns from the two sets of data.



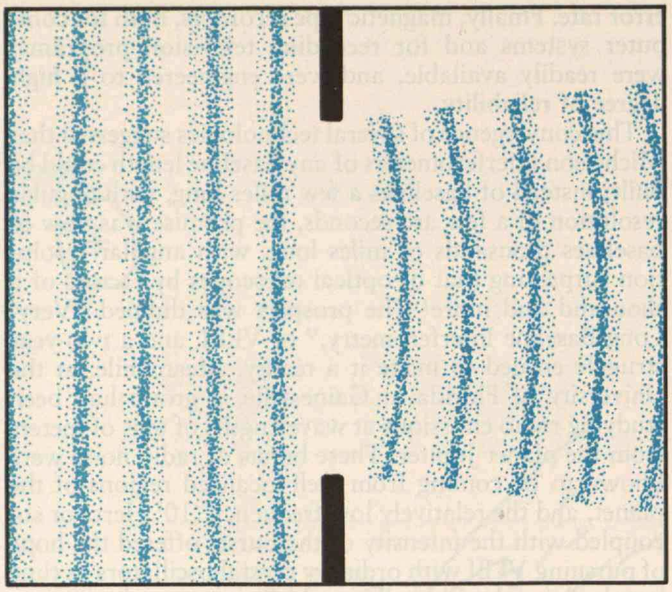


Image degradation by diffraction — a particularly grievous problem for radio astronomers. In both drawings, radiation arriving from the left encounters an aperture. At first, the aperture is as wide as one wavelength of the radiation; wave fronts are distorted as they pass through this hole, spreading into an angle of one radian, or about 57 degrees. The problem grows less severe as the aperture's size, measured in wavelengths of the incoming radiation, is increased; in the drawing at the right, the aperture is five wavelengths wide, and the radiation spreads into an angle of only one-fifth radian.

Other molecules, notably interstellar water vapor, share this behavior.

The M.I.T. group had been able to show, via conventional interferometers, that the OH maser sources were small in size, and there was a strong suspicion that they could be very small indeed. We all knew of the VLBI efforts, with quasars as their target, and we knew that the observations had not yet succeeded. The difficulties were sufficiently numerous to give any experimenter pause: The signal from the quasars was weak — much weaker than the noise generated by the receiving amplifiers. This meant that long time-averages had to be carried out. Furthermore, a very complicated combination of electronic devices had to function perfectly at each station. Finally, not only did the atomic clocks have to provide precise *relative* time, but the starting times of the recordings had to be well synchronized. If any of the fragile links failed, no output would come from the computer, and no way existed of telling which "black box" (or human operator) had gone wrong.

The OH lines seemed to offer several advantages that might result in easier experimental work. The signals were strong — stronger than the noise generated in the receivers at the antenna. The signals were narrow band, since they were lines, and a much narrower recording bandwidth was possible. Finally, in having a very narrow-band spectrum, the signals Fourier-transform into a wave that is nearly sinusoidal. The effect is exactly analogous to the "ringing" phenomenon familiar to the electrical engineer, the mechanical engineer, and the acoustics expert. Any system that has a well-defined resonance will continue oscillating, or ringing, long after its original excitation has ceased. This meant that the exact synchronization of the clocks was a less critical matter — even a rather large timing error could be tolerated. The combination of a very strong signal and relative insensitivity to timing errors seemed to offer hope of expediting the first demonstration of the VLBI principle.

As luck would have it, all the groups converged on results at roughly the same time, and in the order in which they had started their projects. In late April of 1967, the Canadian group performed a successful VLBI experiment at 50-centimeter wavelength, using the 85-foot Penticton, B.C. telescope and the 150-foot Algonquin Park telescope north of Ottawa; the group observed fringes from several quasars. In early May, the NRAO-Cornell group performed a 75-centimeter experiment with the NRAO 140-foot telescope in Green Bank, West Virginia and the Naval Research Laboratory 85-foot telescope at Maryland Point, also observing quasars. In late May, the M.I.T. group successfully performed a VLBI observation of the 18-centimeter OH lines in the ionized hydrogen region W3, a gaseous nebula in the constellation Cassiopeia. Thereafter the push to even longer baselines began. No matter how many wavelengths separated the telescopes, successive experiments always showed that some quasars and some astrophysical masers gave measurable fringes. These ever-finer angular details seemed to be justification for seeking higher angular resolution.

The Regions where Stars Form

The diameter of the earth presents one limit to the baselines achievable by radio astronomers today, and so the natural procedure was to press to ever higher frequencies, corresponding to shorter wavelengths, so that the largest possible number of wavelengths should separate the radio telescopes. But as the wavelength becomes shorter, one grows fearful that the earth's atmosphere might destroy the interference phenomena. The two (or more) radio telescopes that form the VLBI system are receiving signals through completely independent samples of the earth's atmosphere, and random phase changes result which ought to be more damaging to small wavelengths. Fortunately, nature has been unexpectedly cooperative, for such has proven not to be the case. The decisive test came through the fortuitous occurrence of a class of natural masers even more powerful than the 18-centimeter OH masers. The water molecule, H_2O, has a natural transition at 1.3-centimeter wavelength (corre-

sponding to a frequency of 22,234.07 megaHertz), but there is enough absorption of this line in the earth's atmosphere to inhibit the use of its wavelength for radio and radar. Looking straight out through the atmosphere, however, the attenuation is not severe, and a group at the University of California at Berkeley discovered that many of the regions of star formation that possessed OH masers also exhibited maser action at the H_2O wavelength. The M.I.T group joined forces with the Naval Research Laboratory, and in December of 1969 a successful interferometer experiment between the Haystack 120-foot telescope and the Maryland Point 85-foot telescope demonstrated that stable interference fringes could be obtained at the H_2O line, and that some of the H_2O masers were smaller in angular size than 0.003 arc-seconds.

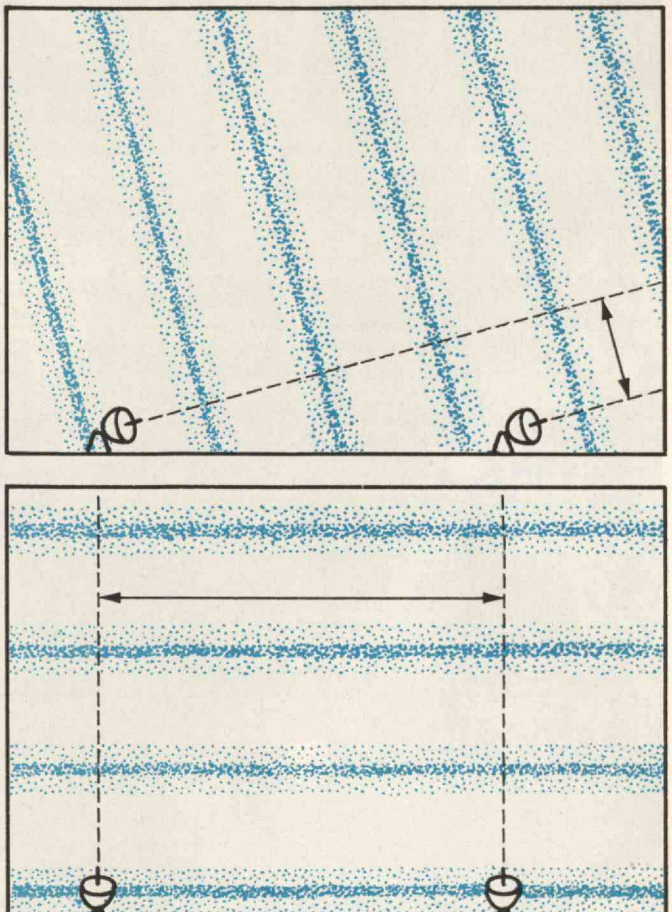
The ultimate in earthbound angular resolution was achieved when the M.I.T. group joined forces in June, 1971 with colleagues in the Soviet Union, and utilized the 22-meter telescope of the Crimean Astrophysical Observatory near Yalta, together with the Haystack 120-foot instrument, to show that measurable fringes in H_2O masers could still be observed. The angular resolution in the experiment was 0.0003 arc-seconds, a record that has still not been surpassed.

In these experiments on astrophysical masers, what has been learned? It is clear that the process is intimately connected with star formation. Masers are always found in ionized hydrogen regions (HII regions) such as the Orion Nebula. In these regions, glowing, ionized gas is kept in an excited state by intense ultraviolet light from very young stars that are always found in the vicinity. In fact, the very youngest stars are buried in the ionized gas of the HII regions, and appear to have formed from the material there. The H_2O masers, found in the midst of this activity, are producing vast quantities of radio noise packed into a single spectral line. The total radio output of the H_2O masers in W49, a very distant HII region on the other side of the Galaxy, is twice as great as the entire energy output of the sun! One major puzzle in the entire complex of maser problems is the source of the "pump" power — the mechanism by which the energy-level population is inverted, thus enabling maser action to proceed. It is clear, though, that the masers appear in compact groups.

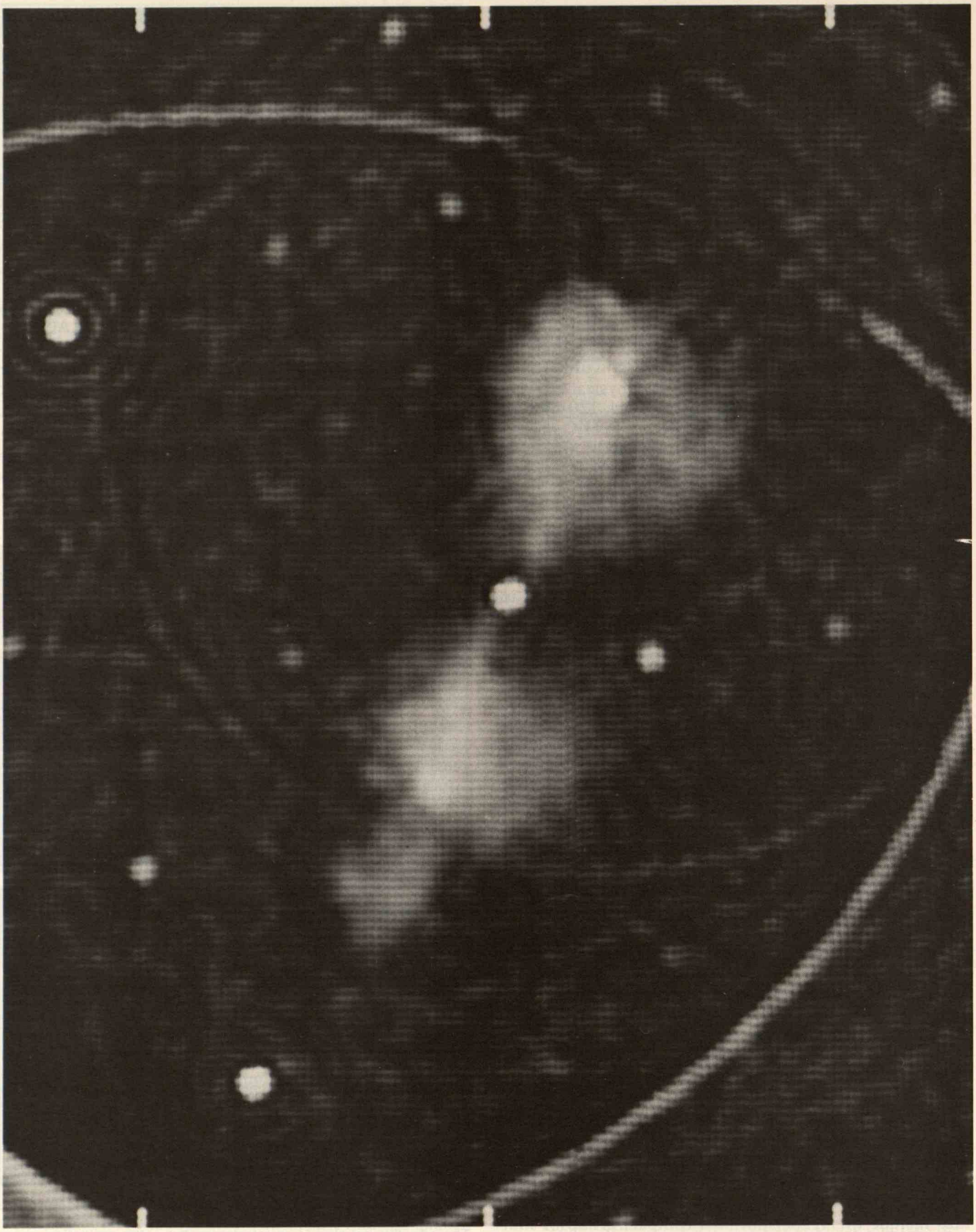
Can the interference fringes be Fourier-transformed to give a high-resolution map of the masers in the sky? Since one must use the radio telescopes already built on the surface of the earth, only a limited collection of interferometer baselines is available, resulting in incomplete measurement of the Fourier transform. Fortunately, even a limited sample of the transform's behavior is enough to show that the masers are a collection of a few compact spots. Such a distribution — a collection of star-like points — has a very simple mathematical description, and one can indeed produce maps despite the limited data. An example is shown on page 50. Here, an optical exposure of the Orion Nebula has been made (using the Hale Observatories' 200-inch telescope). Details near the very bright center of the nebula cannot be seen, but these details include the Trapezium — a compact group of four very young stars at the center of the nebula. The stars are very young indeed, and may have come into being since our Cro-Magnon ancestors appeared only tens of thousands of years ago. There are unseen regions of star formation in the picture — a group of infrared sources that are almost certainly very young stars still cloaked in the dust and gas from which they formed. The H_2O masers are tiny spots scattered about the field of view, with the positions indicated. The spots are tiny indeed — ranging from 0.001 to 0.003 arc-seconds — implying a size not much larger than the young stars of the Trapezium. One word of warning must be given, however: what one "sees" may be very different from the physical form of the maser. A laboratory helium-neon laser, for example, produces a pencil of red light, dazzlingly bright as seen end on, but very dim when viewed from the side. The positions of the spots in the figure are correct, but the sizes must remain uncertain until we understand more about the phenomenon.

Resolution of the Quasars

Quasar studies, in the meantime, have proceeded with vigor. The NRAO-Cornell group became the NRAO-CalTech group as personnel changed their affiliations. A second M.I.T. group, under Professor Irwin Shapiro, came into being, with a group at NASA's Goddard Space Flight Center as collaborators. At first, this second consortium planned to use VLBI as a tool for making measurements of the earth itself. In the interferometer of page 48, it was assumed that the spacing of the antennas was given, and that the position and structure of the radio source was to



The effective spacing of an interferometer — the projection, on a line perpendicular to the line of sight, of the spacing between the two receivers. When the radiation source is low in the sky (top drawing), the effective spacing is a small number of wavelengths; when the source is overhead (bottom drawing), the effective spacing is at its maximum. The variance of this parameter throughout the day is crucial: it allows a single pair of radio telescopes to collect data that are mathematically transformed into maps of the sky.



Radio galaxy DA240. The image was created by Fourier transformation of interference fringes recorded by the Westerbork aperture synthesis instrument, an array of 12 radio telescopes in the Netherlands. The optical galaxy corresponding to DA240 is only 100,000 light-years across; it would occupy the very center of the radio-emitting region shown here, which is doubled in structure and extends across millions of light-years of space. The loops of brightness, called grating sidelobes, are artifacts that result from the incompleteness of the data: only a limited number of baselines can be achieved by the Westerbork instrument, so only a sampling of the Fourier transform can be determined. One sidelobe sweeps across the top of the image, and is due to a radio source at the bottom left; another sweeps across the lower right, and is due to a radio source at the upper left. A third sidelobe circles the upper component of the radio galaxy. The image is reproduced by permission of Leiden Observatory.

be determined. In fact, *all* these quantities are initially unknown, but the distances between radio telescopes are automatically obtained from the interferometric data. Ultimately, it is hoped that the drifting of continents can be directly measured.

The geodetic measurements are simple ones only if the available radio sources are steady. Should the sources vary in position or structure, the problem becomes far more complicated. The astrophysical masers do vary from month to month, and it was hoped that the quasars would be more suitable as test objects. However, both the M.I.T.-Goddard geodesy group and the NRAO-Cal Tech group found that quasars are also active objects, and so the highly precise geodetic measurements had to begin with studies of the celestial objects themselves.

The first series of observations at wavelengths ranging from 3.8 to 2.8 centimeters were alarming, for they seemed to suggest that changes were occurring with great rapidity in quasars. If the distances to these objects were being correctly inferred from their redshifts, motions many times faster than the speed of light seemed to be occurring. There were, of course, many caveats. The Fourier transform of the objects was being sampled in a very incomplete way, so the "maps" were highly ambiguous. The redshift distances to the quasars were perhaps grossly wrong. There was the chance that the apparent motions were not real; just as a series of blinking lights on an advertising sign suggests motion where none exists, so the quasars may be assemblages of flashing radio sources that give the appearance of motion without the substance. Finally, there is the possibility that the laws of physics might truly be wrong in quasars, which are extraordinary objects. The possibility has such deep implications that great rigor should be demanded in the proofs.

Efforts are proceeding to derive more complete maps of the bright quasars. By using as many radio telescopes as possible in simultaneous observations, a more complete Fourier transform can be developed. One such effort is shown on page 44, where the series on the left gives three successive views of the quasar 3C273, the brightest quasar in the sky, and one of the closest, since its redshift implies a distance of merely three billion light-years. Data was collected with Cal Tech's 130-foot telescope, Harvard's 85-foot telescope at Fort Davis, Texas, and the 140-foot NRAO instrument. Over a period of a year, the components changed in relative brightness by significant amounts, and immediately the suspicion arises that the motions appearing to exceed the velocity of light are artifacts. These 3C273 observations are still not true maps, but are models — possible maps — that are consistent with the data.

With presently available baselines, only a very few quasars can be mapped with any completeness: their structures must be simple, and they must be well away from the celestial equator. The quasar 3C345, at a redshift-judged distance four times greater than that of 3C273, appears to be just such a source. The M.I.T. geodesy group, joined by collaborators from NASA and the Chalmers University of Gottenburg, used four radio telescopes — the 210-foot JPL instrument at Goldstone Lake, California, the NRAO 140-foot and Haystack 120-foot instruments, and the 85-foot telescope at Oxsala, Sweden, to produce the map on the right of page 44. The source is double, with only 0.0015 arc-seconds between components, which implies a separation of only about 40 light-years in space. This picture was not derived from a model, but rather was directly produced by taking the Fourier transform of the data. In both cases, 3C345 and 3C273, the best optical-telescope images of these star-like objects would be undifferentiated discs of light about a thousand times larger on the scale of the figure.

The complexity of quasars is probably greater than we suspect. Every improvement in angular resolution reveals more detail. We do not know if they are simply the active nuclei of galaxies or if they represent some entirely new class of celestial object. The studies of radio-emitting galaxies closer to us than the quasars probably favor the first possibility, since we have evidence that radio galaxies exist in which the galactic center periodically expels high-energy particles that generate the radio noise. Such an object, DA240, was mapped by the Leiden radio astronomers, using the Westerbork one-mile aperture-synthesis instrument, and is shown at the left. DA240 is over six million light-years across, making it one of the largest objects we have yet found in the universe. Perhaps the quasars, small and bright, are the prelude to the construction of such vast complexes, but we must await the gathering of more information before we can know.

What does the future hold in store? Clearly we are still far from an explanation of either quasars or interstellar maser phenomena. Producing better pictures will require more complete arrays of radio telescopes, and a group of radio astronomers, representing nearly all the VLBI workers in the world, is assembling a plan to work toward a network of VLBI stations capable of generating complete pictures of stellar objects with better than 0.001 arc-second resolution. This will involve the use of existing radio telescopes in the fullest possible way, and the construction of one or two more radio telescopes, probably in the central and western U.S. Beyond the VLBI network lies the possibility of radio telescopes in space, and discussions between U.S. and Soviet radio astronomers have been taking place. The leap into space is neither easy nor cheap, but the prospect of freedom from earthbased dimensions lends excitement to the future.

Bernard F. Burke received both his S.B. and Ph.D. from M.I.T. His research career began with investigations of molecular structure via microwave spectroscopy. He was co-discoverer of radio noise from Jupiter, and has extensively studied hydrogen structures in the Milky Way. In 1968, he became a participant in the development of Very Long Baseline Interferometry, and has been applying the technique to the study of interstellar masers, galactic structure, and quasars. Dr. Burke is Professor of Physics at M.I.T., and chairman of the U.S. National Committee of the International Astronomical Union.

Author's Note
The radio astronomers who have contributed to the creation of VLBI are so numerous that citations become awkward. Without any intention of slighting individuals by omission, I would like to mention a few whose efforts were especially significant. R. M. Chisholm of Canada and C. C. Bare of the NRAO did not live to see the completion of their works, but they contributed greatly to the groundwork. A. E. E. Rogers of M.I.T., B. G. Clark of the NRAO, and J. L. Yen of Toronto contributed enormously to the conception and building of the complex electronics, while J. M. Moran of the Smithsonian Astrophysical Observatory played a vital role in preparing the computer software.

Suggested Readings

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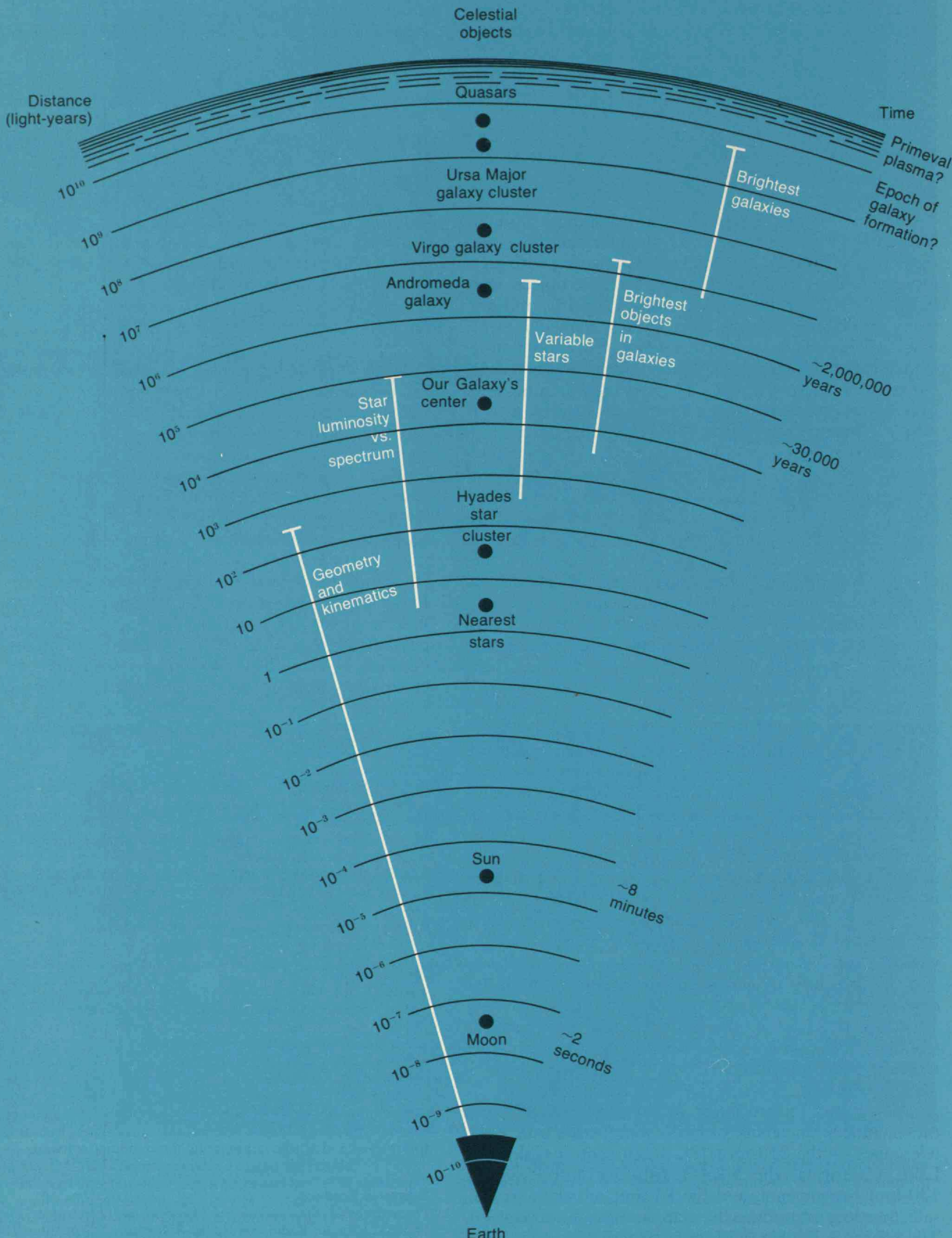
Smith, F. G., *Radio Astronomy,* Penguin (19XX).

Strom, R. G., Miley, G. K., and Oort, J., "Giant Radio Galaxies," *Scientific American,* August 1975, 26-35.



Celestial objects
Distance (light-years)
Time
Quasars
Primeval plasma?
Epoch of galaxy formation?
10^{10}
Ursa Major galaxy cluster
Brightest galaxies
10^{9}
Virgo galaxy cluster
10^{8}
Andromeda galaxy
Brightest objects in galaxies
10^{7}
Variable stars
10^{6}
~2,000,000 years
Our Galaxy's center
Star luminosity vs. spectrum
10^{5}
10^{4}
~30,000 years
Hyades star cluster
10^{3}
10^{2}
Geometry and kinematics
10
Nearest stars
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Sun
~8 minutes
10^{-5}
10^{-6}
10^{-7}
Moon
~2 seconds
10^{-8}
10^{-9}
10^{-10}
Earth

Space is suffused by a remarkably even radiation that may be a remnant from the earliest ages of the universe.

Rainer Weiss
Professor of Physics
M.I.T.

The Oldest Fossil

Every society has created a myth to explain the origin of the world. The Greeks intertwined the creation of the universe with the whims and family squabbles of Uranus and his children. Our civilization may have generated some myths of its own, no less imaginative, guided by our conviction that physical laws are universal and our hope that the universe, on a grand scale, is fundamentally simple and comprehensible. This article is concerned with the observational evidence, meager as it might be, for present-day cosmology.

The Determination of Cosmological Distances

The vast scale of the universe is suggested by the illustration at the left, in which various celestial objects are placed according to their distances from earth. Time is part of such a picture, for we observe these objects not as they are now, but rather as they were when the light we now receive left them — the sun as it was eight minutes ago, the center of our galaxy as it was approximately 10^4 years ago, the nearest neighboring galaxy as it was 10^6 years ago, and so on. The determination of the distance scale is a story compounded of ingenuity, guess work, and careful observations. For relatively local objects, the methods are those discussed earlier in this issue by Jeffrey E. McClintock: the distance to the sun and other nearby stars is established geometrically, much as a surveyor would establish the distance to a remote landmark using triangulation. Here, the base of the triangle is the diameter of the earth's orbit around the sun, determined by prior triangulation using the earth's diameter as the base. By measuring angles as small as 0.03 seconds of arc, the distances to approximately one thousand stars have been determined. Other, more subtle kinematic methods that use the motions within nearby clusters of stars, especially the Hyades cluster, permit distance determinations for a few hundred more stars. These methods, with present-day techniques, carry the distance scale out to about a hundred light-years.

Larger distances are determined by measuring the brightnesses of distant objects. If the absolute luminosity — the entire light output — of a source is known, a measurement of the light incident on the earth gives the distance to the object, for the observed brightness of a source diminishes with the square of the distance. The problem is knowing the source's absolute luminosity, and correcting for the attenuation of its light by intervening matter such as interstellar dust. The absolute luminosities of the nearby stars are easily established because their distances are known geometrically. The light from these stars has been analyzed, and relations between a star's absolute luminosity and its spectral characteristics — the relative strengths of different atomic spectral lines — have been discovered. Accordingly, the first extrapolation in the distance scale is to identify the spectra of more distant stars, and use the relation between spectral type and intrinsic brightness to estimate these stars' absolute luminosities. This scheme extends the distance scale to the dimensions of our own galaxy, but stars in other galaxies are not bright enough to permit spectroscopic studies with existing telescopes.

The next step involves bright stars that pulsate: the so-called Cepheid variables and RR Lyrae stars. These objects are sometimes found in star clusters whose distances can be determined by applying the relation of spectral type and luminosity to non-pulsing stars within the cluster. In this way, it was found that a relation exists between a variable star's period of pulsation and its absolute luminosity; and through this relation, the variable stars extend the distance scale to other galaxies in our local cluster of galaxies.

Using the brightest objects in a galaxy — clusters of stars or regions of ionized, luminous gas — extends the scale to the Virgo cluster of about 2,500 galaxies. In more distant galaxies one can no longer resolve individual objects, so the luminosities of entire galaxies, as calibrated and classified in the Virgo cluster, are used in the next extrapolation. The overall scheme is quite clear: a standard luminous object is identified and assumed to have the same nature whatever its distance. When that standard becomes too faint, a brighter standard is found and calibrated by standard sources of the previous step. If one standard in the distance scale changes, all the following standards will change as well, which has happened several times as new corrections for attenuation or as further subclassifications of the standard sources have been made. The distance scale to the farthest galaxies has expanded by a factor of almost ten since the beginning of universal cartography in the early 1920s.

The scale of the universe. Distances of objects close to the earth are established by geometric methods similar to those used in surveying, and by analysis of motions within nearby clusters of objects. The values derived in these ways are used to calibrate the next step outward, which employs stellar spectra. The last steps bring us to vast distances — 10^7 light-years and more — where the galaxies seem to be receding. Remoteness in distance corresponds to remoteness in time; somewhere beyond 10^{10} years ago, according to big-bang cosmology, is a primeval plasma from which the universe evolved.

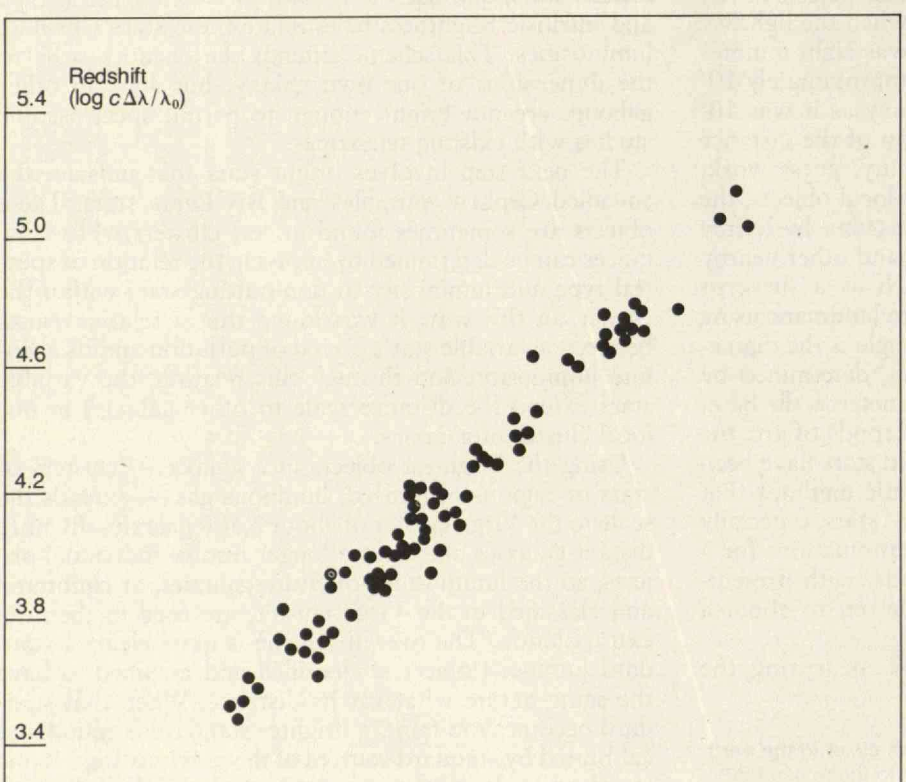
Modern Cosmology

A major finding was made in the 1920s by Hubble and his collaborators, and has been considerably refined by Sandage in the past decade: the very distant galaxies — 10^7 light-years and farther — show a shift of their spectral lines toward longer wavelengths. The shift is proportional to the wavelength; its relative value is the same for a host of spectral lines measured in the same galaxy; and it seems to be proportional to the galaxy's distance from earth.

The most widely held interpretation of the shift involves the Doppler effect — the change in received wavelength due to the velocity of a radiation source relative to a receiver. The Doppler effect is used by highway patrols at microwave wavelengths to measure the velocity of cars. If the same effect accounts for the galaxies' wavelength shifts, then the linear increase of the shift with distance yields a profound conclusion: by following the implied trajectories of the galaxies back in time, one finds that about 10^{10} years ago the entire universe was concentrated into a small volume. By this interpretation, the spectral evidence forms the cornerstone of modern cosmology — the notion that we live in an expanding universe which had an explosive origin about 10^{10} years ago. Other explanations for the spectral shifts have been proposed, such as a time-variance in the fundamental constants of nature, or the hypothesis that light becomes "tired" on its journey from distant galaxies. However, these explanations require a change in accepted physical laws. At present the Doppler interpretation is the one that leads to the fewest inconsistencies.

The picture of a uniformly expanding universe with a linear relation of velocity to distance conjures up the idea of a center for the expansion, but this does not have to be the case. Imagine a bag full of small bubbles, and, neglecting the walls of the bag, assume that some mechanism makes all the bubbles grow uniformly. The center of each bubble moves away from the center of every other with a velocity proportional to the distance between the bubble centers. In short, there is no "preferred" bubble. This model also highlights two assumptions that are enshrined as Cosmological Principles. The first is that on scales of 10^8 to 10^9 light-years, the universe looks the same in all directions — there are no preferred axes. This is the principle of isotropy. The second is that each place in the universe is equivalent to every other place at the same time. For example, the mass density or the temperature is the same everywhere at the same instant. This is the principle of homogeneity in space. In the standard cosmological model, there is, however, no homogeneity in time. The universe evolves from its highly condensed phase, so there is a built-in clock that can be read by looking at the changing physical parameters throughout the universe.

In the mid-1950s Bondi, Gold, and Hoyle developed a steady-state cosmology that removed the inhomogeneity in time. In this theory, the universe maintains a constant aspect to all observers for all time. It is an attractive theory, but also a vulnerable one, as any evidence for cosmic evolution could be used as an argument against it. The progenitors of the steady-state theory reckoned with the expansion of the universe by hypothesizing a new piece of physics: the continuous creation of matter



A Hubble diagram, using Sandage's data, that shows the wavelength shift vs. corrected magnitude for the brightest galaxy in each of 84 galaxy clusters. Increasing magnitude corresponds to fainter and more distant sources. The original Hubble data would lie within the small box near the origin.

throughout the universe to maintain the mass density at a steady-state value.

Background Radiation and the Cosmic Explosion

The steady-state cosmology has come on hard times in the past few years with a discovery that is the subject of the remainder of this article. The story of the discovery is in the best traditions of scientific research, containing elements of accident, forgotten predictions, old puzzles solved, and new ones generated. It begins in 1965 with an observation made at Bell Laboratories by Penzias and Wilson of unexplained noise in a carefully designed antenna system used to receive signals from the Echo communications satellite.

Noise is the most common form of electromagnetic radiation in nature. Made audible, it sounds like the hiss between FM stations on a radio; made visible, it looks like the snow on a television set tuned to an unused channel. Noise is random, but its power spectrum — the amount of energy in a range of frequencies — is a measurable quantity that can be related to physical processes occurring in the noise source. A classic and limiting example is the radiation emitted by matter at a given temperature. The temperature is a measure of the energy associated with chaotic motion within the matter — for example, the random motion of electrons in a metal or molecules in a gas, or charged particles in a plasma. As these constituents collide and accelerate, they emit radiation. The net result is noise — an incoherent radiation by the entire system of colliding bodies. If the system is at thermal equilibrium — all parts at the same temperature — the power spectrum of the noise is determined exclusively by the temperature, and is independent of the details of the source. Moreover, the power spectrum of such a source is characterized by a peak occurring near the frequency where a photon's energy would be equal to the average thermal energy of the matter. At low frequencies, the spectrum grows with the square of the frequency; at high frequencies, it drops exponentially with frequency.

For the Bell Laboratory researchers to find an unexplained excess noise required that they make an absolute measurement — they had to understand all the noise sources in their antenna and receiver system. The noise in the receiver could be measured by looking into a source at the temperature of liquid helium. The noise from the atmosphere could be measured by changing the elevation angle of the antenna, thereby altering in a calculable way the number of molecules, and hence radiators, in the antenna beam. The noise generated by the antenna itself, and in particular the radiation from the ground that was diffracted into the antenna, had to be estimated, as it could not be easily measured. During 1964 and 1965, the researchers at Bell made measurements, and after subtraction of all the known effects, there remained an excess noise at a wavelength of seven centimeters that was unpolarized, isotropic, independent of the season, and apparently coming from a source at 3.5 ± 1.0 °K.

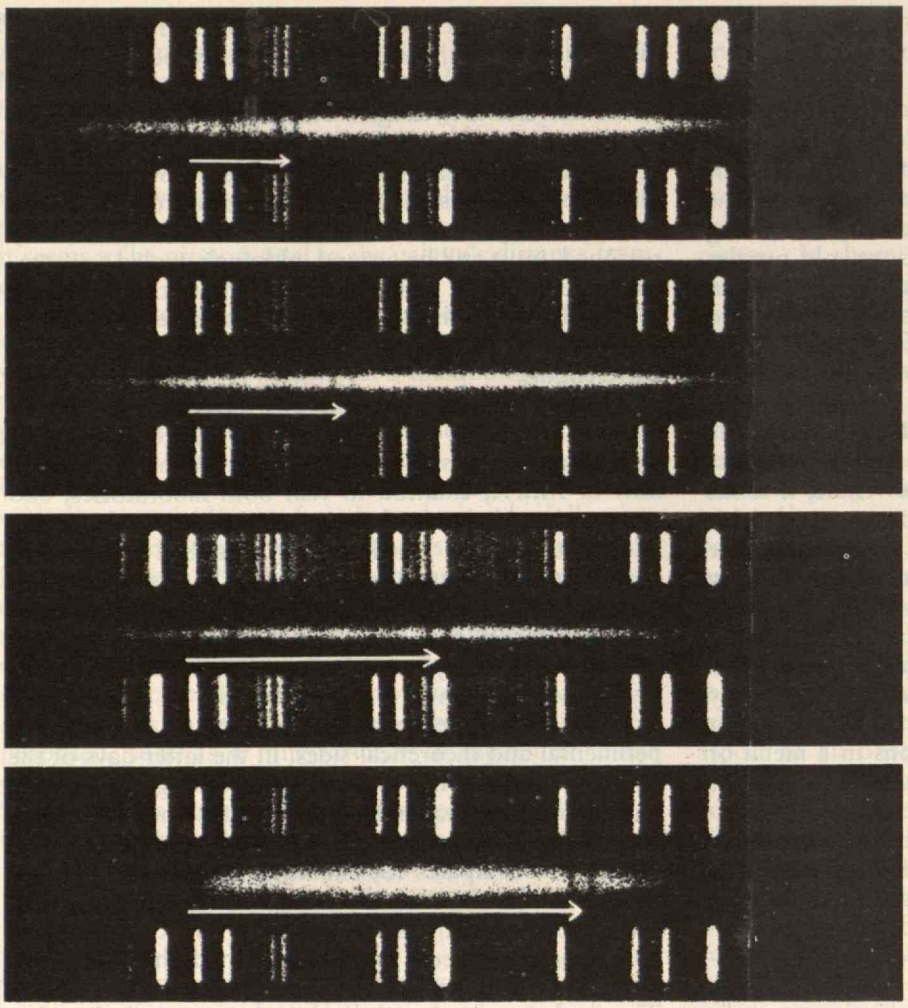
Meanwhile, at Princeton University, Dicke and his group were pondering the properties of a universe that expands, and then, having sufficient mass density, contracts under the influence of gravitational attraction until a critical density is reached. At that point, the universe might blow up and begin a new cycle. The group's interest in this oscillating cosmology had to do with the abundances of the chemical elements: if the oscillations had been going on forever, most of the matter in the universe should be locked into silicon and iron, whose nuclei have the highest binding energy per proton or neutron. However, the most abundant element observed in the universe is hydrogen. The group argued that in an oscillating universe, the highly condensed phase must be hot enough to break the heavy nuclei into their fundamental constituents, giving the universe a fresh start with each cycle. The thermal radiation from that epoch, they reasoned, must still be around, although cooled to somewhere below 40 °K by the universal expansion. At Princeton, Roll and Wilkinson began to set up an experiment to measure this background radiation at three-centimeter wavelengths.

While the Princeton group was setting up its experiment and the Bell Lab experimenters were performing their measurements of the excess noise, Bernard F. Burke, now of M.I.T., chanced to visit both laboratories, and communicated the work going on in one to the other. Shortly thereafter, the Princeton and Bell Laboratory groups published measurements of the background radiation and an interpretation of the radiation as a remnant of the primeval cosmic explosion — possibly the most important discovery in cosmology since Hubble's discovery of the recession of distant galaxies.

There are more elements in the story, on both the experimental and theoretical sides. In the latter days of the M.I.T. Radiation Laboratory, Dicke along with others had carried out measurements of the absolute sky brightness at three centimeters, using a Dicke radiometer — a device that compares the radiation coming from an antenna with that from a cold source — and had established that the sky brightness was less than 20 °K. The finding had apparently been forgotten, as had the theoretical work of Gamov and his collaborators in the late 1940s. They had attempted to show that given an exploding, hot universe — the big bang cosmology — it should be possible to predict, knowing the reaction rates in nuclear processes, the relative abundances of all the isotopes. The assumption was that the universe began hot and neutron-rich, and that all the elements were created early in the expansion by successive neutron capture. The universe had to be hot to avoid trapping too many of the neutrons in helium nuclei. The theory ran afoul because there are no stable nuclei with mass 5 (a helium nucleus plus a proton or a neutron) and mass 8 (two helium nuclei). Thus the formation of elements by the addition of a neutron to light nuclei is interrupted at these two masses, and the generation of heavier nuclei requires slower and more complicated interactions for which there was insufficient time and density in the explosion. Buried in the calculations, though, was a prediction that the radiation from this early hot phase should still be around, but at a temperature of approximately 5 °K.

A Test of the Cosmic Origin

The early history of the universe, as it is understood now, begins with a highly condensed and extremely hot phase, with density and temperature so remote from our direct experience that we can only speculate about the physical processes that might have been occurring. At 10^{12} °K, however, the universe has a density comparable to that of the atomic nucleus. It fits into a volume the size of the solar system, and contains only subatomic particles — specifically electrons, positrons, neutrinos, muons, and a sprinkling of baryons — and a large number of photons. A few minutes later, the universe has cooled to 10^9 de-



The relation between redshift and distance for four galaxies. In each spectrum, an arrow shows the shift in two calcium lines. If this shift is due to a recession velocity relative to the earth, then a galaxy in Ursa Major (uppermost spectrum in the illustration) is rushing away from us at 15,000 kilometers per second. The recession velocity is currently taken to be 50 km/sec for every million parsecs (3.25 million light-years) of the distance from earth to the galaxy. Accordingly, 15,000 km/sec corresponds to a distance of 10^9 light-years. The second spectrum is that of a galaxy in Corona Borealis; its redshift corresponds to a velocity of 22,000 km/sec and a distance of 1.4×10^9 light-years. The third spectrum is that of a galaxy in Bootes (39,000 km/sec; 2.5×10^9 light-years). The fourth is that of a galaxy in Hydra (61,000 km/sec; 3.96×10^9 light-years).

grees, and some element synthesis is possible, creating both helium and deuterium. After about ten thousand years, the universe has cooled to around 10^4 degrees, and it is now cold enough for the plasma of electrons and protons to combine into hydrogen atoms. This epoch is called the time of decoupling, for matter and radiation cease to interact on any time scale comparable to the expansion rate. The universe becomes transparent, in the sense that radiation has a vanishing probability of ever being scattered by matter again. Thus the fossils remaining in their pristine state from this early epoch may include the radiation — and perhaps also the helium and deuterium nuclei, provided we understand their production in stars.

If matter and radiation were in thermal equilibrium just prior to the time of decoupling, the spectrum of the radiation should be a thermal one. This thermal nature should be preserved throughout the ensuing expansion, although the temperature decreases inversely as the scale of the universe because of two factors: the Doppler effect and a reduction in the photon density. Accordingly, a critical test of the cosmic origin of the background radiation is whether it has an essentially thermal spectrum. Shortly after the radiation's discovery, many measurements at the low-frequency end of the spectrum were made, all confirming that the spectrum increased with the square of the frequency. However, it is possible to invent quite plausible sources with spectra that vary in the same way in this frequency region. For example, the radiation from hot, tenuous dust, or the radiation from a gas of colliding charged particles could mimic the thermal spectrum at long wavelengths.

The burning issue became whether the spectrum had a peak at the appropriate frequency. The peak of a 3 °K thermal spectrum occurs in an unfortunate region of the electromagnetic spectrum: at millimeter wavelengths, where the earth's atmosphere is almost opaque, the instrumentation is still primitive, and the radiation from hot objects becomes especially troublesome. The first clue that the spectrum at least stopped rising with the frequency squared came from an indirect and elegant observation — but not a new one. For many years prior to the discovery of the background, it had been known that the cyanogen molecule, CN, as observed by its spectrum in interstellar molecular clouds, appeared to be anomalously excited. It was noted that the molecule absorbed stellar radiation not only by transitions from its lowest energy state to higher states, but also by transitions from its next lowest state, which had an energy difference from the lowest state equal to the energy of a photon with a wavelength of 2.6 millimeters. By measuring the ratio of these absorptions, it was calculated that the CN molecule appeared to have a distribution of states appropriate to a temperature of 3 °K. Not much had been made of this, as the interstellar medium is quite complicated, and an explanation invoking collisions with charged particles might have explained the anomoly. Now it was quickly realized by Field and Thaddeus that the anomoly might be the response of the molecule to being bathed in the background radiation. In effect, interstellar molecules

could be used as frequency-selective thermometers in space. The idea was put on a sounder footing by several measurements of CN absorption spectra in interstellar clouds of varying illumination and charged-particle density. In all cases the excitation temperature was measured to be around 3 °K; in no case was it significantly less than 2.7 °K.

Direct measurements around the peak and toward higher frequencies have had a stormy history. The measurements had to be made using well-shielded cryogenic instruments above the bulk of the earth's atmosphere, as the radiation from any source at room temperature, including the instruments themselves, is approximately a thousand times as intense as the power at the peak of the background radiation. At higher frequencies, the unfavorable ratio grows larger exponentially. The first direct measurements were carried out in the late 1960s from both rockets and high-altitude balloons. The rocket payloads employed broad-band detectors that measured the total power in the background radiation; early results indicated that there was an enormous excess — a factor of approximately 50 over the power expected from a 3 °K. thermal source. The first balloon payloads investigated the spectrum in three broad regions; these results indicated that the background had an overall excess but that it might be concentrated in narrow spectral features. It happens that both observations were wrong. By 1972, results obtained primarily from balloon platforms established that the spectrum had a peak and was consistent with a thermal spectrum for 2.7 ± 0.2 °K. Further measurements using balloon platforms and broad-band instruments did not seem profitable, as the atmospheric radiation, even at an altitude of 40 kilometers, overwhelms the background radiation at frequencies above the thermal peak. In the last year, however, several balloon experiments carrying high-resolution spectrometers to "look" between the atmosphere's narrow radiation lines have confirmed the existence of the thermal peak and measured the spectrum toward higher frequencies.

The most restrictive measurements of the background spectrum are gathered together in the illustration on the next two pages. As is obvious from the figure, the spectrum is not yet well-known — certainly not well enough to draw any far-reaching conclusions concerning small deviations from a thermal curve. Further measurements of the spectrum are now excellent candidates for space missions, as the same technology developed for rocket and balloon payloads could perform vastly improved measurements in space.

Isotropy and the Early Universe

In their original paper, Penzias and Wilson noted that the background radiation had the same magnitude to within 10 per cent, independent of where in the sky their antenna was pointed. This apparent isotropy is a second test of the background's cosmic origin, for if the sources of the radiation are nearby — say, in the solar system — they most likely would be concentrated in the ecliptic, the plane that includes the orbits of the planets and most of the asteroids, and if the radiation is of galactic origin, the sources would most likely be concentrated in the galactic plane — the plane of the Milky Way. Of course, these two possibilities are not exhaustive: one could argue that the radiation comes from a thin shell of dust surrounding the earth or a spherical halo of sources in our Galaxy. However, as more became known about the spectrum of the background radiation, and as more was calculated about the effects (such as scattering and absorption of radiation at other wavelengths) of the hypothetical sources, these possibilities became more and more untenable.

One hypothesis had to be taken seriously: the possibility that the background was the aggregate of radiation from many distant, discrete sources, such as galaxies, with spectra that, due to the expansion of the universe, had shifted into the millimeter and submillimeter wavelength band. There are, however, several difficulties with this explanation. The observed background spectrum would require sources having peculiar spectra individually — spectra that are not observed in ordinary galaxies. Furthermore, it would require a great number of sources. Hard limits on the minimum number have been determined by what are called small-scale isotropy experiments, using radio telescopes at the low-frequency end of the background spectrum. The idea of the experiments is to measure the radiation from a small patch of the sky, the smaller the better, and then to compare it with radiation coming from a different patch of equal size in another part of the sky. On average, the temperature measured for all the patches will be 3 °K, but there will be a fractional fluctuation from patch to patch. Statistical analysis of these fluctuations gives an estimate of the average number of hypothesized sources per patch. The results of the experiments indicate that the background radiation is so smooth, so lacking in graininess, that even the present limits of measurement would require 10^6 times as many sources per solid angle of the sky as have been measured optically. It now seems highly unlikely that the background radiation can be produced by distant, discrete sources.

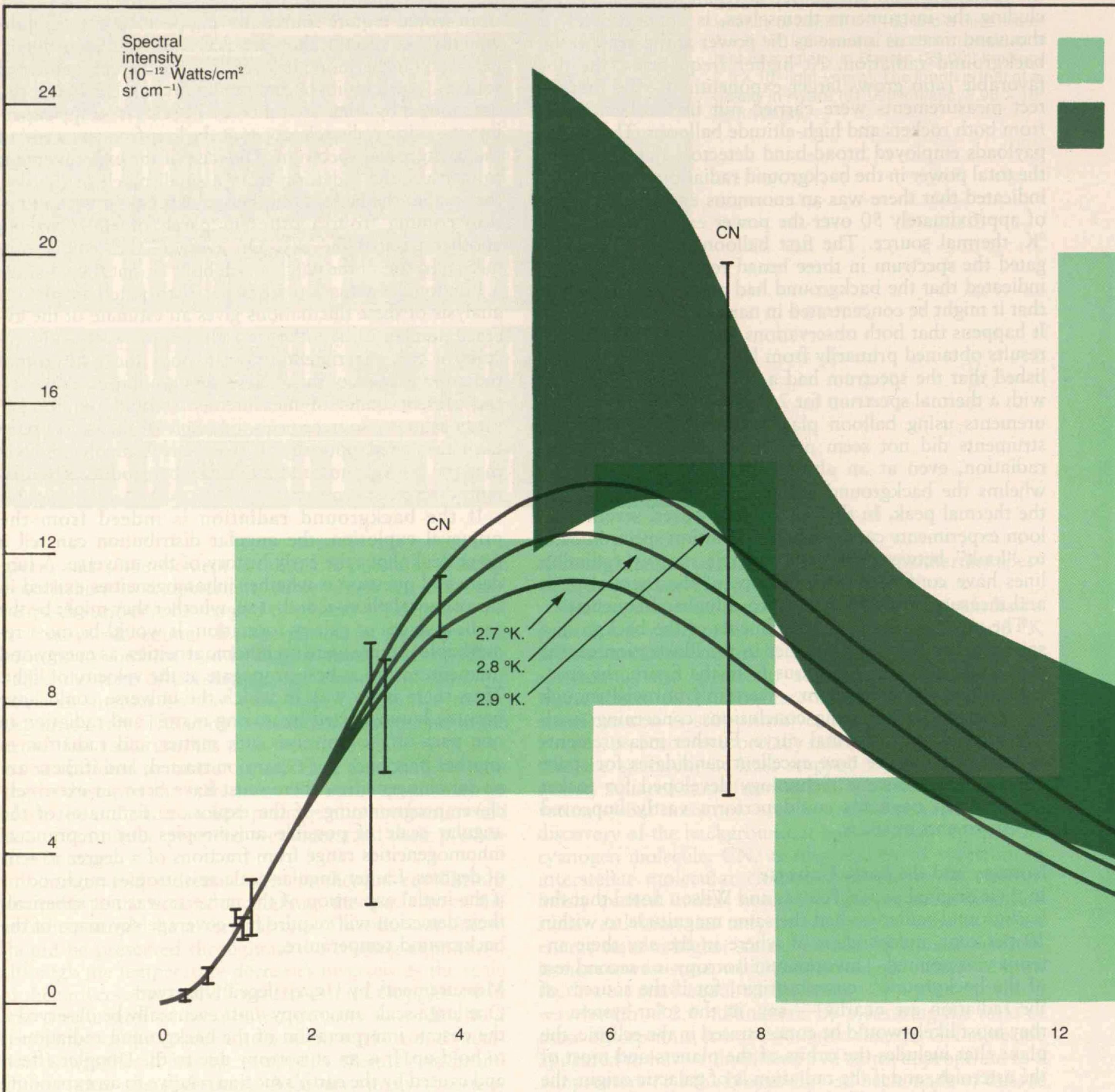
If the background radiation is indeed from the primeval explosion, the angular distribution can tell a great deal about the early history of the universe. A fundamental question is whether inhomogeneities existed in the primeval plasma, and, if so, whether they might be the earliest stages of galaxy formation. It would be most remarkable if there were no inhomogeneities, as energy and momentum can at best propagate at the velocity of light. Thus there is no way in which the universe could have become homogenized by mixing matter and radiation in one part of the universe with matter and radiation in another part once the expansion started, and if there are no inhomogeneities, there must have been an extremely clever programming of the explosion. Estimates of the angular scale of possible anisotropies due to primeval inhomogeneities range from fractions of a degree to tens of degrees. Larger angular-scale anisotropies might occur if the initial expansion of the universe was not spherical; their detection will require full-coverage sky maps of the background temperature.

Measurements by Unprivileged Observers

One large-scale anisotropy *must* eventually be observed if the cosmic interpretation of the background radiation is to hold up. It is an anisotropy due to the Doppler effect, and caused by the earth's motion relative to an expanding frame of reference determined by the universe — more precisely, by the earth's motion relative to a reference frame fixed to the matter that last scattered the background radiation. It is possible to determine if an observer is at rest with respect to this frame because only such observers would see the universe receding from them

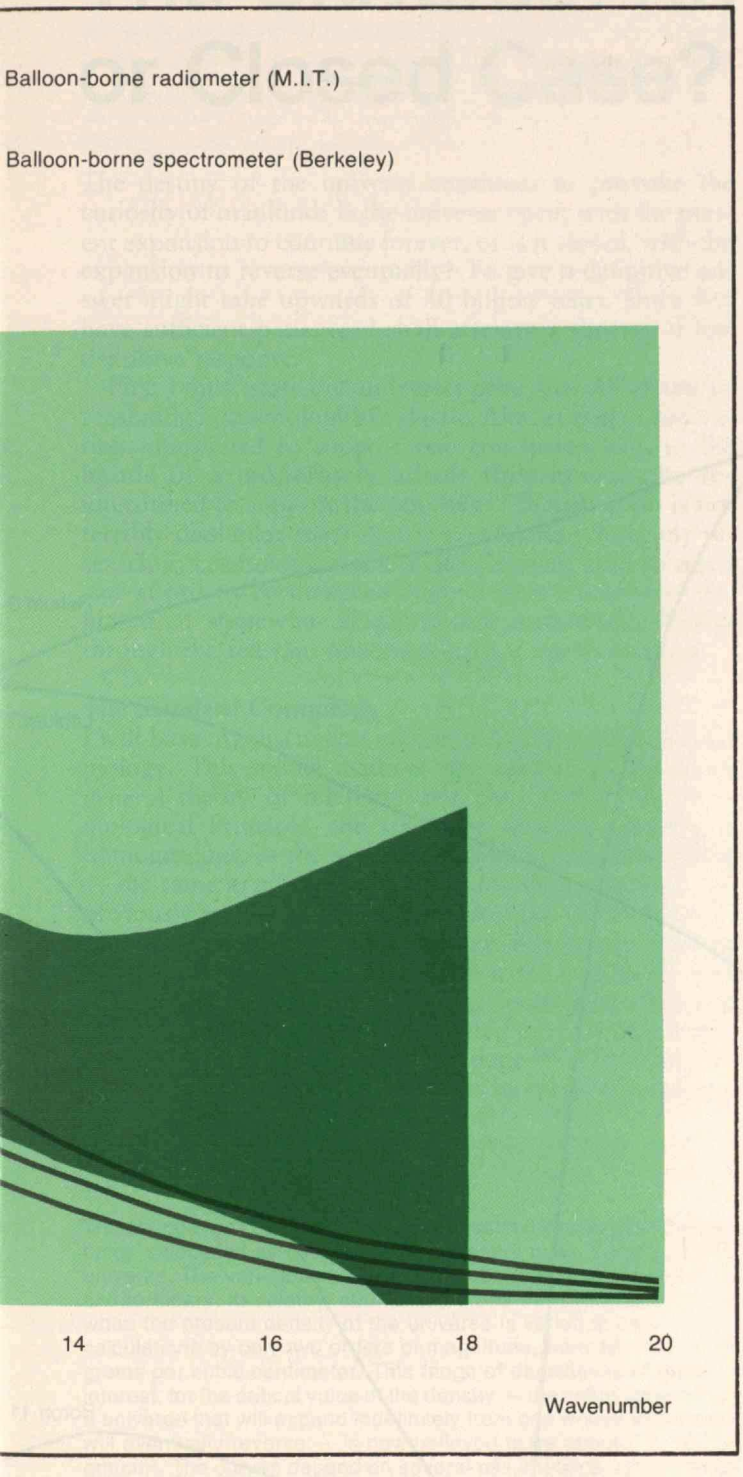
isotropically. Moreover, only they would observe the background radiation to have the same temperature in all directions (assuming, of course, that there were no intrinsic anistropies in the primeval plasma). The model of a uniformly expanding bag of bubbles may help in visualizing this. The privileged observers are those riding with a bubble — they observe the expansion and the background radiation to be uniform. Other observers, moving through the bubbles, observe a velocity-to-distance relation and a radiation temperature that depend on the direction in which they look.

Now the earth cannot be at rest in the privileged frame of reference. We live far from the center of our own galaxy, and are known to have an orbital velocity about the center of approximately 300 kilometers per second. Furthermore, our galaxy is moving relative to other members of our local cluster of galaxies, with velocities that are typically a few hundred kilometers per second. The local cluster of galaxies may have a peculiar velocity (not part of the general recession), again in the neighbor-



Measurements of the background radiation are compared with thermal (black-body) curves for 2.7, 2.8, and 2.9 °K; if the radiation is truly a remnant from the early universe, its spectrum should be a thermal one. Two of the measurements at specific single frequencies derive from observations of the spectra of interstellar cyanogen (CN), while the others are measurements made at microwave frequencies by earthbound antennas. The leftmost such measurement is that of Penzias and Wilson; made at Bell Laboratories, it was the first detection of the background radiation, and was reported in 1965. The areas shown in shades of green are

hood of hundreds of kilometers per second. It is possible, but not very likely, that all these velocities cancel. Even so, there remains our motion around the sun, which changes direction throughout the year and has a magnitude of 30 kilometers per second. All these motions should affect our observations of the background radiation: its spectrum should be a thermal one in all directions, but it should appear hottest in the direction of our motion relative to the privileged frame of reference, and cooler in a way that varies as the cosine of the angle between our viewing direction and our velocity.



measurements made by instruments carried above the bulk of the earth's atmosphere by balloons. The light green areas are limits set on the energy within relatively wide bandwidths; the dark green area shows narrowband measurements.

Large-scale isotropy experiments have been carried out from the ground in the low-frequency end of the spectrum for several years. A technique used by the Princeton group is to compare the radiation from a fixed point in the sky — the region around the North Star — with the radiation that the antenna samples along the celestial equator as the earth turns. Other experiments have taken the difference between the radiation entering antennas pointing east and west at a fixed elevation angle, again using the earth's rotation to scan the sky. Experiments are now in progress to measure the anisotropies from balloon platforms; this should reduce the noise from atmospheric inhomogeneities and also extend the frequency range toward shorter wavelengths. It has already been discovered that on angular scales of 10 degrees and larger, the background radiation is remarkably — in fact, alarmingly — isotropic, to within about 0.1 per cent. This indicates that the primeval plasma was extremely homogeneous, and furthermore that the earth has a velocity less than a few hundred kilometers per second relative to the privileged frame. No measurements have convincingly established any particular velocity.

Large-scale anisotropy experiments will continue from balloon, and ultimately from spacecraft, platforms to map the entire sky at many wavelengths and with a range of angular resolutions. The goal in the next few years is to measure the anisotropies to a level of 0.01 per cent, which should be sufficient to determine the anistropy due to our motion around the sun. A major question is the level at which anisotropies due to local sources begin to dominate. At low frequencies, the galactic plane is a powerful source that must be removed from the data, while at frequencies above the thermal peak, galactic dust clouds must be considered. It appears that the region between one centimeter and one millimeter wavelengths may be the least perturbed by local sources, but even here it will be important to measure the anisotropy at several wavelengths, as the spectrum of the anisotropy is needed to discriminate discrete sources from intrinsic anisotropies in the background radiation.

The background radiation may indeed prove to be the oldest fossil — a relic that has remained intact since almost the beginning, and has inscribed upon its spectrum and angular distribution the early history of the universe. Better measurements will certainly reveal new and fundamental properties of the universe. It is not a matter of achieving another decimal point, but rather that more precision is needed to uncover the important effects.

Rainer Weiss is an experimental physicist. His research has included measurements of hyperfine structure in atomic and molecular spectra, the development of instruments to search for effects associated with gravitational fields, and, most recently, in collaboration with Professor Dirk J. Muehlner, measurements of the background radiation discussed in this article. This latter work includes a large-scale anisotropy experiment which is in progress. Dr. Weiss received his S.B. and Ph.D. from M.I.T. After five years in positions at Tufts and Princeton Universities, he returned to the Institute, where he is now Professor of Physics.

Suggested Readings

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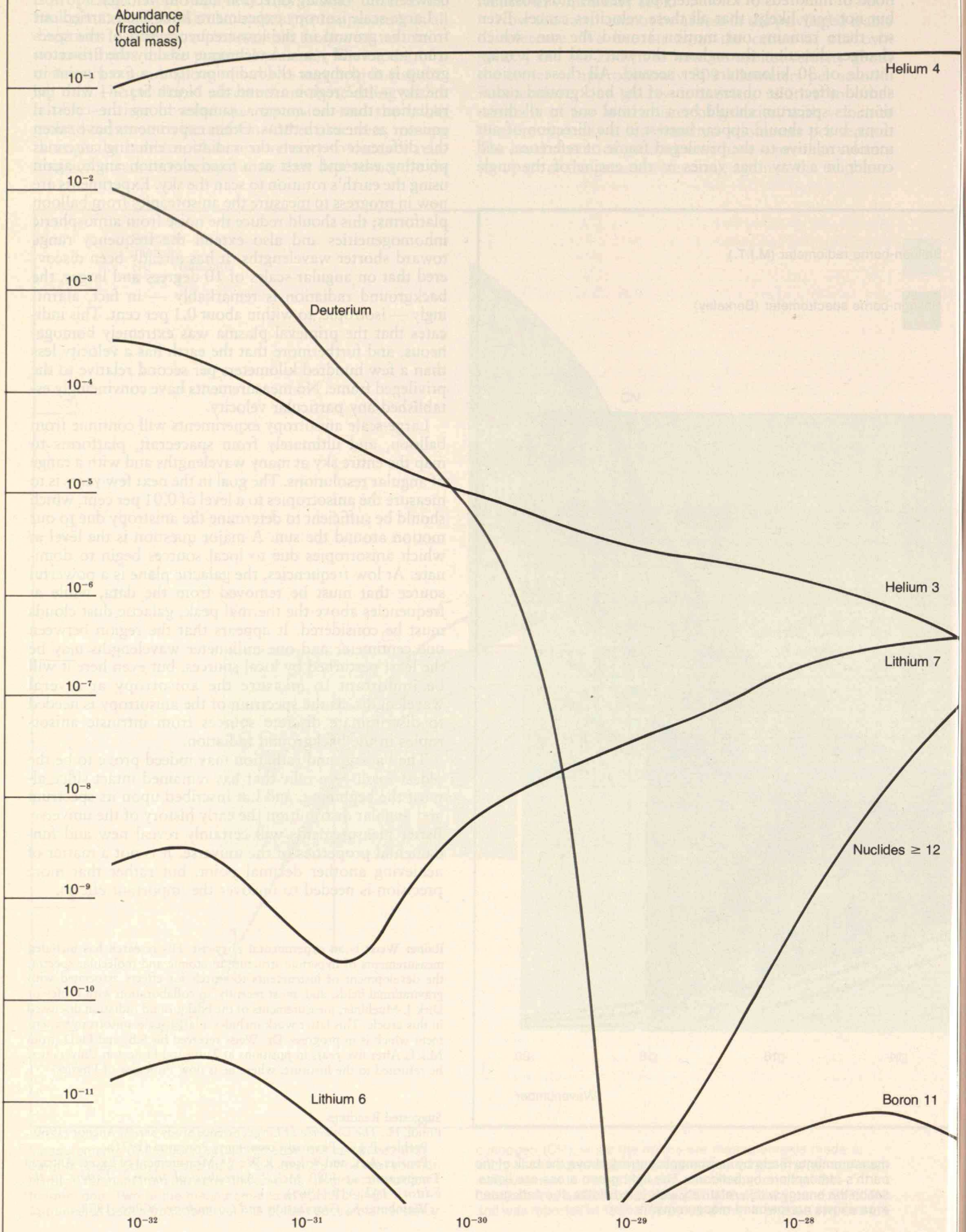

Abundance (fraction of total mass)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Helium 4
Deuterium
Helium 3
Lithium 7
Nuclides ≥ 12
Lithium 6
Boron 11
10^{-32}
10^{-31}
10^{-30}
10^{-29}
10^{-28}
Present density (grams per cubic centimeter)

Deuterium may play a key role in predicting the fate of the universe.

Irwin I. Shapiro
Professor of Geophysics and Physics
M.I.T.

The Universe: An Open or Closed Case?

The destiny of the universe continues to provoke the curiosity of mankind: Is the universe open, with the present expansion to continue forever, or is it closed, with the expansion to reverse eventually? To give a definitive answer might take upwards of 30 billion years. Since few have sufficient patience, I shall attempt a shorter, if less definitive response.

First I must state one universal principle: All chains of reasoning in cosmology are elastic. Almost every observation interpreted to support one conclusion can, in the hands of a moderately adroit theoretician, be reinterpreted to support the opposite. (The situation is not terribly dissimilar from that in economics.) Since my research in cosmology is not widely known, even to me, I can afford to be detached and to steer a relatively unbiased, if somewhat skeptical and incomplete, course through the relevant observations and interpretations.

The Standard Cosmology

I will base my discussion on the Standard Model of Cosmology. This model assumes the validity of Einstein's general theory of relativity and also invokes the Cosmological Principle: the statement that the universe is homogeneous — the same at all points — and isotropic — the same in all directions. These twin assumptions are obviously untrue on the scale of this page, or the earth, or the solar system, or even the Galaxy. But they do seem to have some credence on scales still small compared with the size of the universe: the many thousands of known galaxies, for example, are distributed over the sky with a near uniformity, as illustrated on page 70. The outstanding virtue of this standard model is its relative simplicity, which allows computations to be made that can be confronted with observations.

The space-time structure of any homogeneous, isotropic universe can be characterized by two quantities. One, usually denoted $R(t)$, describes the change with time of the scale of the universe — its expansion or contraction. The other, a constant k, is related to the three-dimensional (spatial) curvature of the universe; with an appropriate choice of units k has only three possible values: -1, 0, and $+1$. For $k = +1$, the spatial universe can be envisioned as the analog of the surface of a sphere. The only difference is that here the "surface" is three-dimensional, not two-dimensional. $R(t)$ can be thought of as the radius of the sphere. Such a spatial universe is clearly finite, but unbounded — it has no "edges." For $k = -1$ or 0, no simple interpretation is available; the universe is infinite and non-Euclidean. In the standard model, through the use of Einstein's equations from the general theory of relativity, the variation of R with time can be determined in all three cases. At the time of the famous "big bang" (part of the standard model), R is zero; it then grows with time, most rapidly and in an unbounded manner for $k = -1$: the "open" universe. For $k = +1$, R reaches a maximum at some future time (30 billion years hence?) and then decreases back to zero: the "closed" universe. The "boundary" between these two cases is marked by $k = 0$ although here, too, R increases without bound, as illustrated on the next page.

For a discussion of universes with such symmetric structures, it is convenient to use *comoving coordinates*. In this system, the spatial coordinates of each "average" galaxy remain fixed as the galaxies partake in the expansion that follows the big bang. The galaxies are like an array of dots affixed to the surface of a balloon being inflated. The universal time coordinate is proportional to the (atomic) time kept by each comoving observer (or "dot"). Any comoving point can serve equally well as the spatial origin of the universe.

Given this framework, how can one decide, observationally, whether the universe is open or closed? As we shall see, the function $R(t)$ would yield the answer, if only it could be evaluated. Since we are located in the universe at the present epoch, say $t = t_0$, and are also limited in our "vision," we can evaluate R only in the neighborhood of t_0. It is therefore useful to make a Taylor series expansion of R about t_0. The first term in this expansion, R_0, is the scale of the universe at the present epoch. The coefficient of the second term, after division by R_0, is called Hubble's constant, H_0, and corresponds to the

The abundances of various nuclei synthesized shortly after the big bang, calculated as functions of the present mass density of the universe. The variation in the primeval abundance of deuterium is extraordinary: its relative abundance drops from 10^{-3} to 10^{-12} when the present density of the universe is varied in the calculations by only two orders of magnitude, from 10^{-31} to 10^{-29} grams per cubic centimeter. This range of densities is of great interest, for the critical value of the density — the value separating a universe that will expand indefinitely from one whose expansion will eventually reverse — is now believed to be about 7×10^{-30} gm/cm^3. The curves depend on several assumptions, among them that the standard model of cosmology, described in the text, is valid, and that the universe is suffused by a background radiation whose temperature is now 2.7 °K. The number following an element represents the number of its nucleons. (From D. N. Schramm and R. V. Wagoner, *Physics Today*)

local rate of expansion discovered by Edwin Hubble about a half-century ago. This constant has dimensions of inverse time. In fact, in the standard model, H_0^{-1} is closely tied to the age of the universe — the elapsed time since the big bang. For reasons related to astronomical measurements, H_0 is usually expressed in kilometers per second per megaparsec (km/sec-Mpc; a parsec is about 3.25 light-years). The negative of the coefficient of the third term, after modification by suitable factors of H_0 and R_0 to render the result dimensionless, is called the deceleration parameter, q_0. This parameter is expected to be positive since the gravitational attraction between the galaxies acts to retard the expansion of the universe.

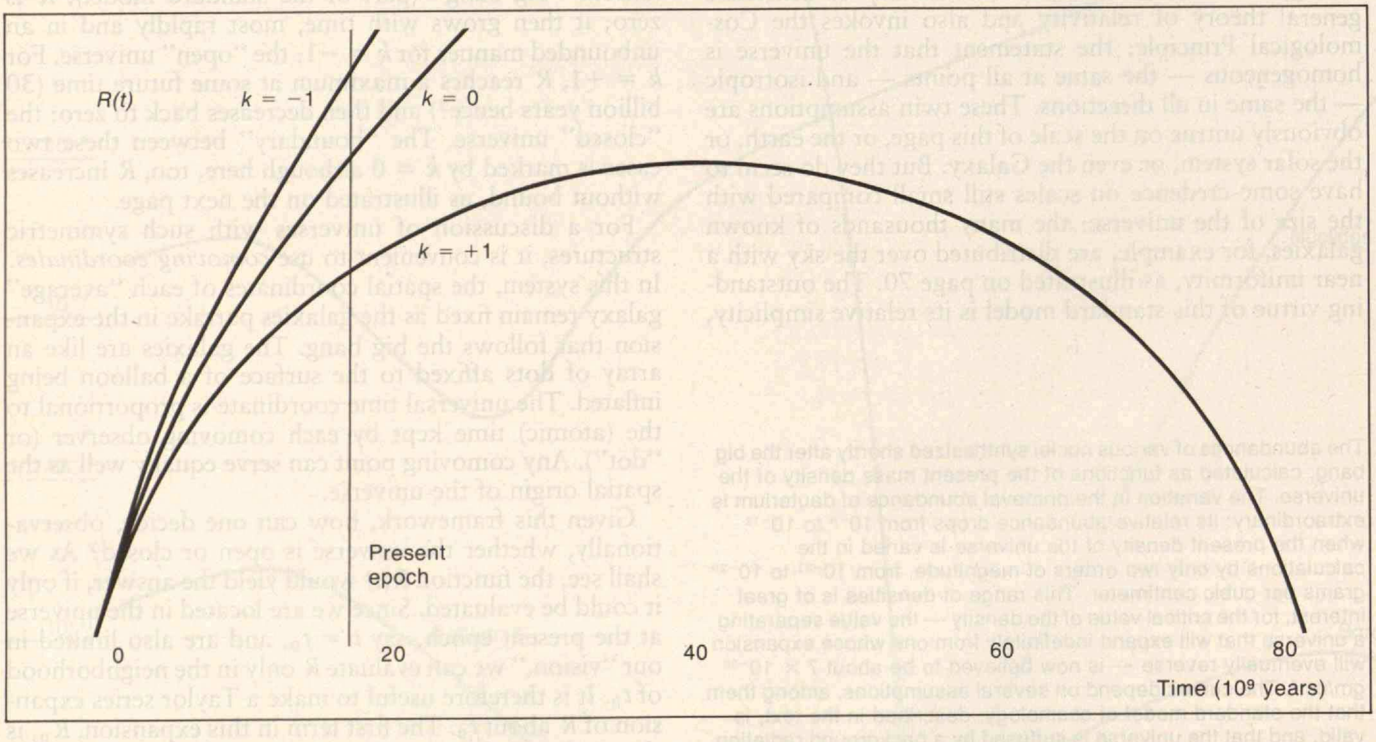
Within the confines of the standard model, the evaluation of q_0 reveals the destiny of the universe. The equations of general relativity, and the apparently valid assumption that, suitably compared to the density, the pressure in the universe is negligible at the present epoch, lead to a simple relation between q_0 and the curvature-related constant k. The value $k = -1$ (open universe) manifests itself as $q_0 < 1/2$, and $k = +1$ (closed universe) is implied by $q_0 > 1/2$. Equivalently, we can cast the question in terms of the universe's present mass-energy density, ρ_0. If this density is sufficiently large, the implied strength of self-gravitation will prevent the universe from continuing forever to expand. The critical density, ρ_c, that separates the scenarios of open and closed universes is proportional to H_0^2. The faster the expansion at a given epoch, the greater is the mass-energy density required to maintain the universe in a bound state, for the magnitude of the gravitational potential energy must exceed the kinetic energy of the expansion for the universe to be bound.

The Velocity-Distance Relation

Deciding whether the universe is open or closed thus devolves upon our ability to determine whether q_0 is below or above one-half or, equivalently, whether ρ_0 is below or above ρ_c. Historically, a number of combined observational-theoretical techniques have been applied in attempts to make this decision. The first technique, developed by Hubble himself, was based on the idea that by observing very distant objects, which corresponds to looking deep into the past, one could, in effect, determine the spatial curvature of the universe and q_0. Simply observing these objects is obviously not sufficient to determine q_0. One seeks both the apparent radial velocities at which they are receding, and the distances to them. The desired curvature manifests itself in the non-linearity of the relation between these apparent radial velocities, or recession velocities, and the corresponding distances. The constants H_0 and q_0 follow rather straightforwardly from this "velocity-distance" relation.

Unfortunately, obtaining reliable data is less straightforward. Of the two types required, the recession velocity is much the easier to obtain. If the light from a distant object exhibits spectral lines, and if these lines can be identified reliably as being characteristic of given atomic transitions, then the Doppler shift, or "redshift," of the lines can be interpreted easily in terms of a recession velocity. Referring this velocity to comoving coordinates requires the additional knowledge of the "peculiar" velocities of the object and of the earth — that is, their velocities relative to these comoving coordinates. Statistics from relatively nearby objects indicate that such velocities are of the order of a hundred kilometers per second. Hence, if many galaxies with apparent recession velocities of several thousands of kilometers per second are analyzed, the average effects of the peculiar velocities can be reduced to a benign level.

The problems posed by distances are far more profound: no useful single standard of measurement, analogous to the redshift, is available. As a result, a cos-



The only three possible destinies for the universe, according to the standard model of cosmology. For a curvature-related constant k of $+1$, the universe is closed: its present expansion eventually reverses. For a k of -1, the universe is open: it expands indefinitely. For the boundary case, corresponding to a k of 0, the expansion also continues indefinitely, but more slowly.

mic distance ladder was created with each rung dependent on a different standard. Give or take several powers of ten in distance, the rungs are equi-spaced on a logarithmic scale; the entire ladder is shown on page 56. The lowest rung, characterized by the earth-sun distance, is known in laboratory units with an uncertainty of under one part in 10^8, thanks to radar observations of the planets. The accuracy degrades rapidly thereafter. The second rung relies on observations of stellar parallaxes, made possible through use of the earth's yearly motion around the sun to provide the baseline. But these yield uncertainties as low as a few per cent only to distances of about a parsec, which encompasses only the very closest stars. The third rung is an especially slippery one; it depends on kinematic methods that involve statistical interpretations of the motions of groups of stars to give the distances. For example, the velocities of the members of a "moving cluster" of stars are assumed equal and parallel. Then a comparison between their (very small) *angular* velocities across the sky, given by a series of photographs taken over a period of years, and their *radial* velocities, given by redshift measurements, yields an estimate of the distance to the cluster, essentially by dimensional analysis. The Hyades cluster of stars is the eponym of this method, which is useful up to distances of the order of a hundred parsecs. The fourth rung, usable to about a million parsecs, depends on variable stars — R. R. Lyrae and the brighter Cepheids — whose absolute, or intrinsic, luminosities are functions of their periods of variability. These functions are not so sharply peaked as one would like, and other properties, such as spectra, are used to pin down the distances to within, at best, 10 per cent.

The Cepheid rung carries the distance scale to nearby galaxies where the cosmologically interesting region begins. But further extension of the cosmological frontier is difficult. What one seeks, of course, is a standard candle that can be observed everywhere (deep in space and back in time) and calibrated nearby, using the lower rungs of the distance ladder. Nature does not seem to have been so kind. Even if she has, no one has yet found out about it. The higher rungs therefore depend on a mixed bag of techniques based on, for example, exploding stars, emissions from regions of ionized hydrogen, brightest stars in galaxies, globular clusters of stars, and the luminosities of suitably chosen members of clusters of galaxies. Among other difficulties, these luminosity-dependent rungs require corrections for interstellar absorption of light, contributions from stray light, and the redshifts of the spectra. For the very distant galaxies, the proper correction for evolution is perhaps the most crucial: Are these objects intrinsically brighter or dimmer than their older brethren? If so, by how much? Although considerable labor by theorists has been expended to determine suitable corrections for the evolution of the luminosity of the various types of galaxies as they age, there is no general agreement yet on the magnitude or even the sign. This lack most strongly affects the determination of q_0, which depends heavily on the velocity-distance relation at large redshifts (and distances).

The values for q_0 published over the past two decades have shown a nearly monotonic downward progression from about four to nearly zero. It is probably fair to conclude that the distinction between a closed and open universe cannot yet be provided by the velocity-distance relation. In this sense, the original Hubble program has failed. However, more reliable results have been obtained for H_0, which now appears to be near 60 km/sec-Mpc with an uncertainty no less than 20 per cent. The value of H_0 is easier to determine because it depends more heavily on the nearer galaxies than does q_0. Curiously, the estimated value for H_0, too, has undergone a nearly monotonic decrease with time, in part for similar reasons, from Hubble's initial estimate of about 500 km/sec-Mpc. But the slope in the variation with time of the estimate of H_0 is now hovering near zero, and consequently the age of the universe is now at about 15 to 18 billion years and holding. This age, incidentally, is consistent with those based on the decay of long-lived radioactive nuclei (studied by practitioners of "nucleocosmochronology"!) and on the inferred evolution of stars in globular clusters. The latter, especially, is based heavily on theory. But both lead to bounds on age of the order of 15 to 18 billion years.

The Present Density of the Universe

In addition to attempts to determine the destiny of the universe from such "global" arguments, "local" methods to estimate ρ_0, and hence q_0, are also popular within certain cosmological circles. Here a typical objective is to estimate the mass-to-luminosity ratio ("mass-to-light ratio") for our Local Group of galaxies and convert this ratio to mass density through multiplication by the luminosity per unit volume of some suitably large and typical region of the universe. The determination of neither part of this product is free from problems. To illustrate, consider the estimation of the numerator of the mass-to-light ratio for the local galaxies. Counting stars and estimating the mass of each is neither feasible nor reliable; one must be more subtle. Thus one notes that this group is dominated by our Galaxy and the Andromeda Galaxy. With only a moderate amount of witchcraft, one then estimates the mass of the entire group by reduction of its dynamics to the ultimate in simplicity, a one-dimensional, two-body problem. The validity of the assumptions underlying these calculations is by no means universally accepted.

The results from such "local" attempts to estimate the average mass-energy density of the entire universe, through use of the homogeneity assumption, have consistently yielded values substantially lower than the critical density, which, for an H_0 of 60 km/sec-Mpc, is about 7×10^{-30} grams per cubic centimeter (gm/cm^3). Questions continue to be raised, however, about the possible existence of "missing mass" — as yet invisible mass of sufficient density to close the universe. Such material may be in the form of black holes, neutrinos, or intense X-rays. Good arguments can be adduced to make each such possibility appear remote, but for many theorists, nagging doubts or favorite candidates remain. Of course, as I indicated, even the calculations of the visible mass alone are not immune to sensible worries.

The Role of Primeval Deuterium

Finally, I shall describe an entirely different approach to the open-closed question. This approach involves the abundance of deuterium and is currently causing considerable excitement among cosmologists. To understand it, we must first consider the scenario for the physical evolution of the universe in the standard model, largely omitted from the earlier discussion.

The Early Universe. At the beginning, the universe sup-

posedly poured forth from a single point — the big bang. The accompanying temperature and density were impressively high, even to astrophysicists. The very early evolution of the universe is often separated into three stages, according to its mass-energy density. The first was characterized by densities greater than 10^{93} gm/cm^3; here the gravitational energy of interaction must have dominated over the electrical energy, even on the scale of elementary particles. The second stage, during which densities decreased from 10^{93} to about 10^{16} gm/cm^3, was a transition period to the third stage (10^{16} to 10^{14} gm/cm^3), which corresponded approximately to densities expected within neutron stars. Our theoretical understanding of none of these stages is particularly profound. In fact, this understanding has been described by some Soviet astrophysicists in a paraphrase of a famous parody due to Averchenko: Of the third stage, it can be said that we know almost nothing; of the second can be said the same; and of the first that it preceded the other two.

More useful statements can be made if we begin to follow the early universe at a still lower density when the absolute temperature, due to expansion, had dropped to a mere 10^{12} °K. [A particle at such a temperature has an energy of approximately 100 million electron-Volts (MeV).] At this time, with the universe barely a fraction of a second old, the proverbial hordes of hadrons — the very heavy elementary particles — should have virtually disappeared, leaving relatively few nucleons (that is, protons and neutrons) and a rapidly disappearing population of pions. It was the Era of Leptons: the particle population was dominated by the light elementary particles like electrons and muons. As the temperature dropped further to about 8×10^{11} °K, muon pairs were annihilated. Soon thereafter the electron and muon neutrinos and their antiparticles decoupled from the rest of the universe: their mean time between collisions came to exceed the expansion time; phrased another way, the density became sufficiently small for the probability of subsequent matter-neutrino interactions to be virtually nil. The remaining electrons, positrons, photons, and (relatively few) nucleons stayed in thermal equilibrium. At the still lower temperature of 4×10^{9} °K, electron-positron pairs began to annihilate faster than they were created. Thus was born the Radiation Era — a photon domination that lasted until most of the protons combined with electrons to form hydrogen atoms, at a temperature of about 3×10^{3} °K. The pressure of electromagnetic radiation (photon pressure) remained important until this time, when the thermal (black-body) radiation giving rise to this pressure decoupled from the matter, as had the neutrinos earlier. The radiation continued to cool as the universe expanded further; its energy density decreased with the inverse fourth power of $R(t)$, and its temperature (T) with the inverse first power, in consequence of the Stefan-Boltzmann law. On the other hand, after the pressure in the universe became negligible, the matter density, ρ_m, decreased as the inverse third power of $R(t)$, implying that ρ_m/T^3 remained approximately constant during the subsequent expansion. By the present era, the temperature of the radiation had decreased sufficiently that its spectrum, according to this scenario, was peaked in the radio region.

Such radio radiation, with a temperature of approximately 2.7 °K, was actually detected a decade ago. Subsequent observations established that this radiation is indeed nearly black-body and isotropic, and therefore has just those properties expected of relic radiation from the early universe, as explained earlier in this issue. The very existence of this radiation is the single most important piece of evidence that supports the standard model of cosmology. No other reasonable explanation for this radiation has yet been proposed. Its present temperature, as we shall see, plays an essential role in the determination of the destiny of the universe.

Primeval Nucleosynthesis. The first formation of the nuclei of atoms (nuclides) occurred early on in the Radiation Era. The entire primeval synthesis took place in a few hundred seconds, less time than some people require to soft-boil an egg, and can be described qualitatively in simple terms. At temperatures above about 10^{10} °K, the ratio of the numbers of neutrons to protons was kept at its thermal-equilibrium value mainly via the so-called weak interactions — the emission of electron antineutrinos or the absorption of electron neutrinos in the conversion of neutrons to protons. This ratio, by virtue of the mass difference between a neutron and a proton, is slightly less than unity. No nuclear synthesis could take place at this high a temperature: any deuterium formed would quickly photo-disintegrate owing to its low binding energy. (A temperature of 10^{10} °K corresponds to an energy of about one MeV, but the binding energy per particle of the neutron-proton pair that makes up a deuterium nucleus is only 1.1 MeV, the lowest by far for light elements.) After the temperature sank to about 10^9 °K, the rate of production of deuterium from direct neutron-proton reactions outstripped the photo-disintegration rate, so the deuterium concentration built up, leading, through other reactions, to the formation of heavier nuclides. Such successive syntheses, however, soon ground to a halt. The further drop in temperature that accompanies the expansion prevented penetration of the "Coulomb barriers": the energy of collision between two nuclides was no longer sufficient to overcome the mutual repulsion of their positive charges.

Each of the stable nuclides created in this stage had a number of nucleons ranging from two to 12, with the notable exceptions of five and eight. Nuclides with these latter mass numbers are all unstable. The gaps thus created played a significant role in preventing any substantial primeval synthesis of elements with nucleon numbers greater than 12. These latter elements were mainly produced much later, mostly in the cores of stars.

The Observed Abundance of Deuterium. Although the lightest elements were produced in discernible quantities during the big-bang nucleosynthesis, it is a fairly formidable task to determine their abundances from observations. Information on present element abundances comes from diverse sources: spectra of stars; emission and absorption of radiation by atoms and molecules in interstellar space; spectra of planetary atmospheres; direct measurements of solar-wind composition; and chemical analyses of meteorites, lunar samples, and the earth's crust. For nuclides that reside in chemically active atoms, there is a special problem: What was the effect of chemical fractionation on the relative abundances of the elements found in a given compound? For example, is the ratio of the numbers of heavy to normal water molecules (HDO/H_2O) found in nature indicative of the "true" ratio of deuterium to hydrogen (D/H)? No — deuterium appears to be chosen preferentially over hydrogen by about

a ten-to-one margin in the formation of water everywhere. This conclusion can be reached, among other ways, by an analysis of the heavy water found on earth and in meteorites, and by comparison of these results with the D/H value obtained from measurements made with the satellite Copernicus. This satellite, because it is above the earth's atmosphere, was able to detect the ultraviolet (Lyman) lines in the spectra of atomic deuterium emanating from interstellar space. Such atomic species are free from direct chemical effects and likely from indirect ones as well.

The D/H ratio obtained recently from these Copernicus measurements was 14 ± 2 parts per million (ppm) — a number that has captured the attention of all big-bang cosmologists. The reason is simple: in the standard model, a reliable value for the primeval deuterium-to-hydrogen ratio forms a basis for the solution to the problem of the open *vs.* closed universe.

Interpretation of the Deuterium Abundance. Let us now consider in some detail the chain of reasoning that allows one to turn a measurement of 14 ± 2 ppm for D/H into a conclusion about the destiny of the universe. The synthesis of the light elements in the immediate aftermath of the big bang, as discussed above, depends sensitively on the precise decrease with time of both the temperature and the matter (primarily neutron and proton) density, ρ_m. Thus, by assuming values for this temperature and density just prior to the period of primeval nucleosynthesis, and by using the known and estimated cross-sections for nuclear reactions, one can calculate from the standard model the abundances of the various nuclei that would result from such conditions. That calculation also yields the evolution of the ratio ρ_m/T^3, which, as mentioned earlier, remains approximately constant during the later stages of the expansion of the universe. Since the present value of the temperature of the relic radiation is known from observations to be about 2.7 °K, the present value of ρ_m follows immediately and is equal to ρ_0, if the matter now dominates the total mass-energy density as is assumed in the standard model. But that density is precisely the quantity we need in order to distinguish an open universe from a closed universe, and, as stated earlier, it is not given by "direct" observations to anything like the accuracy required for this purpose.

Enter the deuterium-to-hydrogen ratio. Since the present density ρ_0 is the only significant "free parameter" in the standard model, one can obviously repeat the calculations in order to obtain various values of ρ_0 and to determine the corresponding deuterium abundances. For the range of possible ρ_0's from 10^{-29} to 10^{-31} gm/cm^3, deuterium is by far the most sensitive discriminant: the calculated primeval abundance of deuterium increases by nearly nine orders of magnitude (D/H changes from about 10^{-12} to 10^{-3}) for this two-decade drop in present density, as shown in the illustration on page 64. This result can be understood semi-qualitatively: For larger values of the present density, one could expect that a larger fraction of the deuterium created in the primeval nucleosynthesis would have been consumed during that period by the production of heavier nuclides. The higher densities that would have prevailed would have led to more of the collisions that produce the heavier nuclear species.

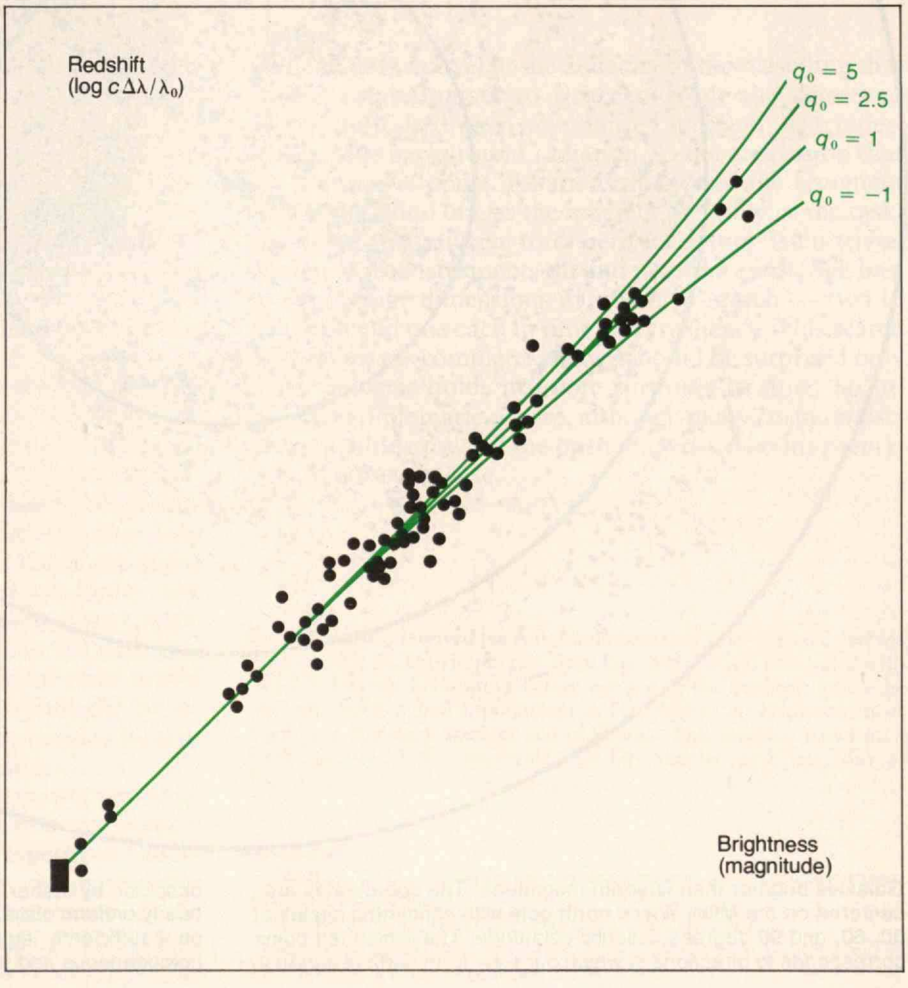
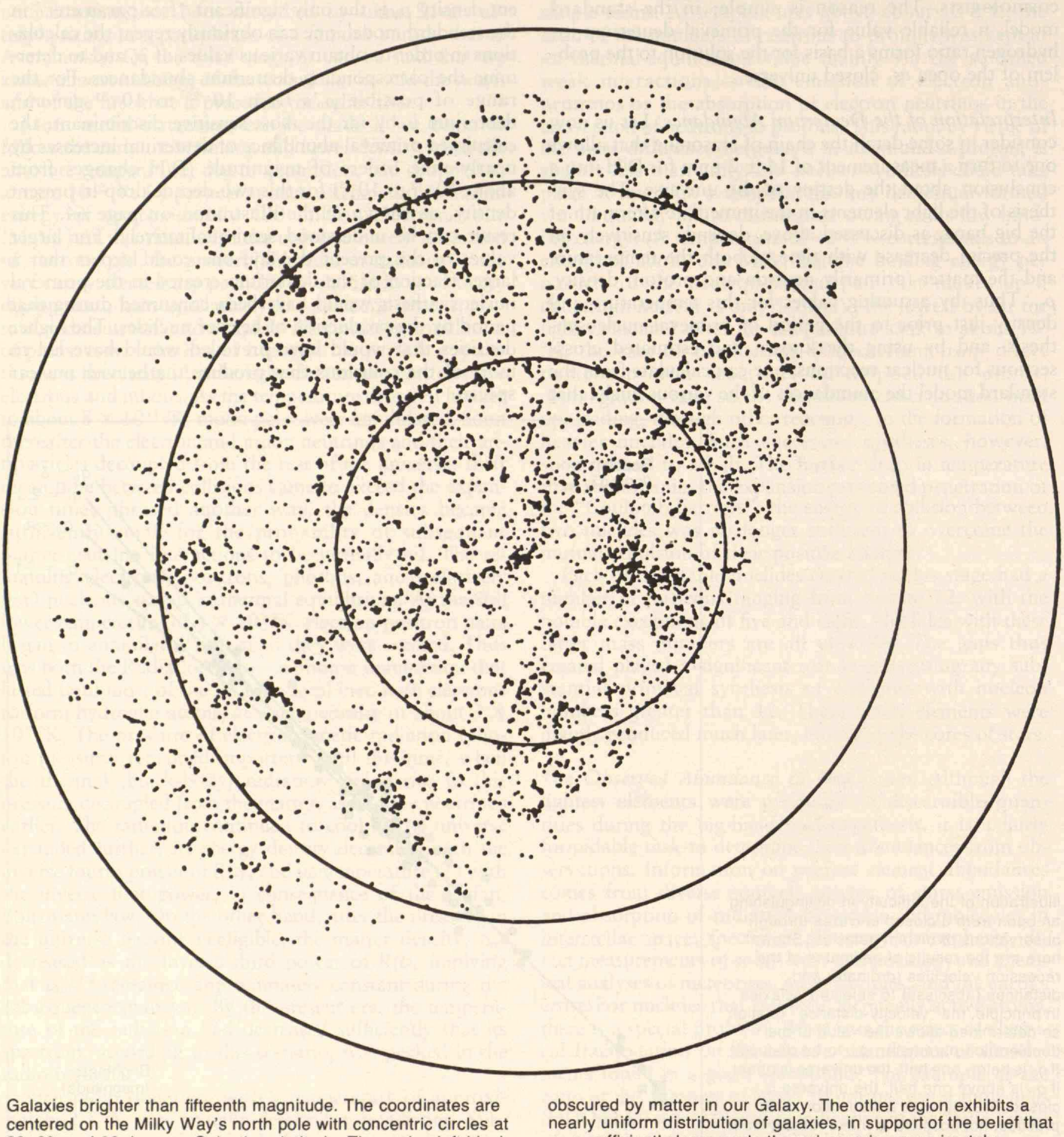


Illustration of the difficulty in distinguishing an open from a closed universe through observations of distant galaxies. Shown here are the results of estimates of the recession velocities (ordinate) and distances (abscissa) to selected galaxies. In principle, the "velocity-distance" relation so determined allows the value of the deceleration parameter, q_0, to be deduced. If q_0 is below one half, the universe is open; if q_0 is above one half, the universe is closed. Clearly such a distinction is, in practice, not possible to make reliably from the available data. (Figure adapted from A. Sandage, *Astrophysical Journal*).

By contrast, normal helium, for example, is a poor discriminant. Virtually all of the neutrons utilized in the primeval nucleosynthesis are consumed by helium. But the neutron density drops due to the combined effects of expansion and decay (free neutrons are unstable) with at first the former and eventually the latter dominating. Hence the calculated primeval helium abundance depends most sensitively on the rate of expansion of the early universe, which in turn depends on its *total* mass-energy density. But, at this stage, the total density is dominated by the radiation, not by the matter, implying that primeval helium is an insensitive indicator of ρ_0. This conclusion is borne out by the detailed calculations illustrated on page 64.

It is the extraordinary sensitivity of the calculated primeval deuterium abundance to changes in ρ_0 that makes the Copernicus measurement of unusual interest. Taken literally, an abundance ratio of 14 ± 2 ppm for D/H implies that $\rho_0 < \rho_c = 7 \times 10^{-30}$ gm/cm³. (The uncertainty in ρ_c contributed by the inaccuracy in our knowledge of H_0 is too small to affect this conclusion noticeably.) If correct, such a density certainly means that the universe is open. It will expand forever.

Other Sources and Sinks for Deuterium. How reliable is this interpretation of the ultraviolet measurements of the deuterium spectrum? Although many feel the interpretation is rock solid, one person's rocks are sometimes



Galaxies brighter than fifteenth magnitude. The coordinates are centered on the Milky Way's north pole with concentric circles at 30, 60, and 90 degrees Galactic colatitude. The region left blank corresponds to directions in which our view from earth is seriously obscured by matter in our Galaxy. The other region exhibits a nearly uniform distribution of galaxies, in support of the belief that on a sufficiently large scale the universe is approximately homogeneous and isotropic. (Courtesy of P. J. E. Peebles)

another's quicksand. What are the possible soft spots? The measurements themselves encompass a number of different spectral lines observed in a number of different directions in the sky. All are quite consistent; further, there are other independent, though less clear-cut, corroborations based on analyses of the rare-gas content of gas-rich meteorites and of nuclide abundances in the solar wind.

Any destruction of primeval deuterium after the period of big-bang nucleosynthesis would only make stronger the case for an open universe; the currently observed abundance would then be an underestimate, requiring a downward revision in the implied value of ρ_0. Within the confines of the standard model, the case can be weakened only by mechanisms that augment the deuterium abundance. The crucial issue thus becomes one of determining which fraction of the currently observed abundance of deuterium is primeval and which fraction was created relatively recently, not in the immediate aftermath of the big bang. Possibilities for such later manufacture include elements synthesized in the cores of stars, and spread by subsequent stellar explosions, and those created by cosmic-ray interactions and by supernova shock waves.

To gain a better understanding of such deuterium-producing processes, let us consider some of their general properties. The synthesis of deuterium in neutron-proton collisions requires free neutrons, which in turn implies high-energy conditions to produce them. Deuterium can also be formed as a spallation product (a "nuclear splinter") in reactions such as those between a proton and a helium nucleus. Owing to the Coulomb repulsion, this reaction also requires a high energy of impact; the threshold collision energy for the production of deuterium is 18 MeV. One must also consider the possibility that these deuterium nuclei are themselves destroyed; avoidance of this fate implies that relatively low densities must prevail.

Where then are the proper combinations of conditions met? The interiors of stars seem to be unpromising sites. Although in current theories deuterium is expected to be produced there via collisions between pairs of protons involving the weak interaction, it is also expected to be consumed quickly by proton collisions which do not involve the weak interaction; almost by definition, the latter proceeds much more rapidly than the reaction that forms the deuterium. The expected equilibrium concentration of deuterium in stars is thus very small. By the same token, any primeval deuterium that went into a star would also have been largely destroyed. This fact is particularly relevant since most modern models of galactic evolution imply that about half of the material now present in interstellar space in our Galaxy has been processed through a star at least once. On this basis alone, one would conclude that the D/H value measured by Copernicus was as much as twofold lower than the primeval value and that the present density of the universe would have to be correspondingly smaller (although, fortunately, not smaller than the lower limits provided by estimates of the density of the "visible" matter).

What other possibilities remain for deuterium production? The two main alternatives advanced so far, as mentioned earlier, involve cosmic rays and supernova shockwaves. Superficially, each appears able to satisfy the joint conditions required for production without too much destruction. For cosmic rays, however, detailed calculations based on measured fluxes and on (mostly) measured spallation cross sections yield abundances adequate to explain the observed abundances for normal lithium and boron, and for neutron-enriched beryllium and boron. But the yield for deuterium fails by more than two orders of magnitude to match the observed abundance (and the yields for some other light nuclides also fare badly in comparison with the results of observations). Thus, to the extent that the assumptions underlying the calculations are reliable, we can rule out cosmic rays as a significant source of interstellar deuterium.

Supernova shockwaves may supply sufficient energy to break up helium directly into deuterium or into nucleons that could recombine to form deuterium. The assumptions upon which these calculations are based are very insecure. As a result, reasonable people can and do disagree about the mechanisms proposed to represent the underlying physics. Many such models have therefore been developed and used in nucleosynthetic calculations, and some actually yield significant increases in the abundance of deuterium. But, no matter, all have an apparently fatal flaw: an appropriate production of deuterium is always accompanied by an excess production of other light nuclides. It is these excesses that cannot be brushed aside. The main problem-children, with excesses from ten- to a hundredfold, are neutron-enriched lithium, beryllium, and boron.

Thus it seems that no viable alternative has yet been proposed to account for the observed abundance of deuterium. If none is forthcoming, and if the precepts of the standard model are correct, we could conclude that the cosmic density is too feeble to prevent the universe from continuing indefinitely to expand.

Caveat

One can only marvel at the audacity of the reasoning that allows cosmologists to proceed from the observed deuterium-to-hydrogen abundance ratio, and the temperature of the background radiation, to the conclusion that the universe is open. Yet the brilliance of the argument should not blind one to the inherent difficulty of the task. Exploring the universe to discern its destiny is no trivial matter. With instruments on and near the earth, one has, in effect, four dimensions in which to search — two in direction and one each in time and frequency. This search is by no means complete, and we should be surprised only if the universe holds no more surprises in store. So, to borrow a diplomatic phrase, although many cosmologists are now tilting toward the open universe, it seems premature to close the case.

Irwin I. Shapiro received his A.B. in mathematics from Cornell, and his A.M. and Ph.D., both in physics, from Harvard. He was associated with M.I.T.'s Lincoln Laboratory before coming to the Institute, where he currently holds a dual appointment as Professor in the Departments of Earth and Planetary Sciences and of Physics. This article is based on a Loeb Lecture of the same title that Dr. Shapiro gave last May at Harvard.

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All 26 Letters in One Great Word?

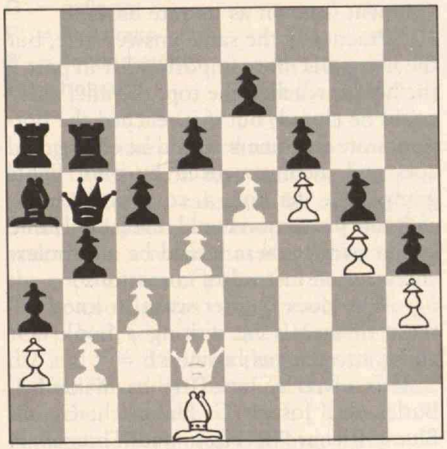
Puzzle Corner
by
Allan J. Gottlieb

Hello again. This month we are instituting a new policy suggested by Frank Rubin. Every other issue I will rummage through back issues and present a problem which has already appeared but was never (completely) solved. Perhaps the challenge of an (allegedly) difficult problem will be an inspiration. These problems will be labeled NS 1, NS 2, ... We begin with NS 1, which originally appeared in 1967.

Solutions to this month's problems will be published in the March/April issue; your responses should reach me by January 5.

NS 1 Let A be a non-empty set of Reals. Call dA = {a − b: a∊A b∊A} the Distance set of A. What can be said about distance sets (measure, closed, connected, etc.)? What are necessary and sufficient conditions for a set, B, to be the distance set of a set?

DEC 1 We begin this month's regular selection with a chess problem from Mike G. Middlebrooke:



White to play and draw.

DEC 2 Frank Rubin wants to know the minimum total area of two circles which cover a unit square. How about three circles? Four circles?

DEC 3 Don Forman is interested in English words which have strings of consecutive letters. For example, PULMONARY contains LMNOP. What is the fewest number of words needed so that the consecutive strings use all 26 letters? (Only one string of consecutive letters is to be taken from each word.)

DEC 4 The following was submitted by Arthur Schach of the National Bureau of Standards: Take two unit squares and place them side by side so they form a rectangle two units wide and one unit high. Now choose a point A at random in the first square and, again at random, a point B in the second square. Then A and B will be a certain distance apart. Question: If we repeat the random choice of A and B many times, how far apart will they be on the average?

DEC 5 The following problem has an interesting corollary as pointed out by the proposer Eugene W. Sard: Show that there is an infinity of trigonometric functions of real numbers that are algebraic numbers. Specifically, given any real number a, where cos a is an algebraic number; if T is any direct trigonometric function, show that T(ma/n) is an algebraic number for all integers m and n. Mr. Sard writes that the implications of this problem "amaze" him: For example, since all the angles in a normal table of natural trigonometric functions are rational numbers of say 30°, all the corresponding function values are algebraic rather than transcendental numbers as he had always assumed. Even Tobias Dantzig in his book *Number, The Language of Science* says that most logarithms and trigonometric ratios are transcendentals.

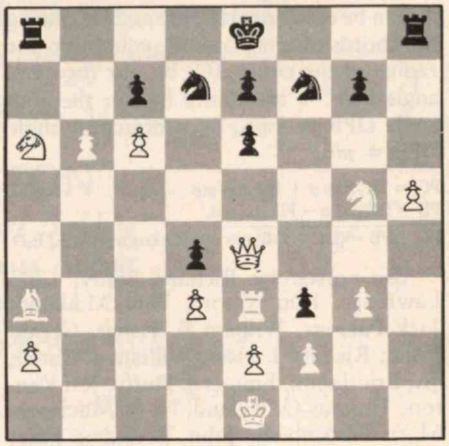
Speed Department

SD 1 R. Robinson Rowe remembers that the Matherville, Mathechusetts, Math Club meets periodically and more often than once a year — always on the 31st day of the month. When is its next meeting?

SD 2 Mr. and Mrs. Victor W. Sauer want you to "add five odd numbers to obtain 14."

Solutions

JUN 1 White to move and mate in two. *(See chessboard at top of next column.)*



It seems to me that Richard I. Hess and William J. Butler, Jr., are correct in their two conclusions:

(1) No mate in two is possible. If Q x P (K6), Castle KR ends the threat; N x P (K6), R x N also seems to lead nowhere. If only White's bishop was on R4, N x P (K6) R x N P x N would be mate. But, alas, it's only on R3.

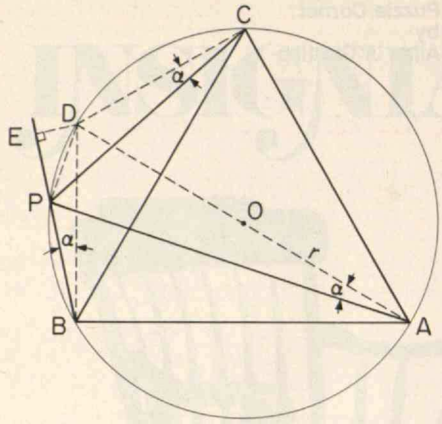
(2) The position cannot be reached in a game. Black has made three pawn captures but White has lost only two pieces.

Responses were also received from Sterling Watson, Herbert Moeller, Robert Aronoff, Jack Hiatt, John Musgrove, Chip Lawrence, M. Michael Laufer, Ron Moore, Frank Danforth, Avi Ornstein, John M. Rand, A. LeBlanc, Gerald Blum, Paul Mailman, Joel Tepper, Eric Jamin, and Jerry (Troll) Schwartz.

JUN 2 ABC is an equilateral triangle inscribed in a circle, and P is a point chosen on arc BC. Prove that AP = BP + PC.

Robert Pogoff points out that this problem already appeared in "Puzzle Corner." Nonetheless, many fine solutions were received. The one presented is from Jack C. Page, who writes:

I find your geometry puzzle most interesting, primarily because I did not suspect that the relationship existed. Once identified it is easy to prove if one remembers the theorem, "Any angle inscribed in a circle is equal to one-half the intercepted arc," and its corollary, "Any angle inscribed in a semi-circle is a right angle." Construct a diameter of the circle through point A, the center O to point D. Drop a perpendicular from D to BP extended at E. By our theorem, angle DAP = angle DBP = angle DCP = ½ arc DP which we will define as α. By our corollary, angle DPA is a right angle. Thus AP = AD cos α = 2 r cos α.



As can be easily proven, BD and DC, being the chords of a $\pi/3$ arc, are equal to r, the radius of the circle AO. By our theorem, angle DPC = $\pi/6$. Since by our theorem angle DPB = $5\pi/6$, by subtraction angle DPE = $\pi/6$.

$$PC = DC \cos\alpha + PD \cos\pi/6$$
$$PB = DB \cos\alpha - PD \cos\pi/6$$
$$\overline{PC + PB = (DC + DB)\cos\alpha = 2r\cos\alpha = AP} \text{ Q.E.D.}$$

Also solved by Richard Brady, Chip Lawrence, Ron Moore, Paul Mailman, Jack Parsons, William B. Fisher, Gerald Blum, Richard I. Hess, William J. Butler, Jr., Eric Jamin, Emmet J. Duffy, Jeff Kenton, Thomas O. Ryland, N. B. Maclaren, Mary Lindenberg, John T. and/or Janet M. Rule, Raymond Gaillard, Victor W. Sauer, Harry Zaremba, John E. Prussing, Ken Kiesel, Roger A. Whitman, R. Robinson Rowe, Robert Gottlieb, Dr. and/or Mrs. Zoltan Cs. Mester, Harvey Elentuck, Naomi Markovitz, Joseph G. Haubrich, Dave Taenzer, and the proposer, George T. Marcou.

JUN 3 Given: one local gas company's old-fashioned storage tank. It floats like a rigid balloon, open end down, on a water sump. Vertical guides restrain it sideways but let it move up and down as gas is pumped in or out. Problem in ten parts:
1. Serve up a proof without numbers that as the tank goes up the gas pressure inside goes down (or up, or remains constant).
2. Is the sump a cylindrical hole or an annular moat (and no fair asking anybody around the gas works; they have lost the blueprint)?
3. A. The tank is half full (or half empty), no gas is added or removed, but the barometer drops. Does the tank go up or down? (*Yes* is not an acceptable answer.)
B. What about the water level(s)?
4. Would it make any difference in *3* whether the hole was annular or cylindrical, or other?
5. Would it make any difference in *3, 9, 10,* if the hole were filled with mercury or olive oil instead of water?
6. Would the tank top be a good place for a penthouse? Or a heliport?
7. Could you employ an escalator to get there and back?
8. With a decorated tank that rotates for advertising purposes, what precautions are required against freezing?
9. If the tank never goes all the way to the top, was it built too large? Does evaporation let the gas company make money on vapor?
10. Same, if it never goes all the way to the bottom? How can the interior be checked out for corrosion?

R. Robinson Rowe claims first-hand experience:
That old-fashioned gas storage tank was called a "gas holder."
I know how it works because 70 years ago a miniature was set up in our basement on the farm, using acetylene generated from calcium carbide instead of "manufactured gas" from coking coal which filled the big one in town. The lower part was called the tank and was nearly full of water. The upper part was the hood and I will call its upper flat surface the deck and the cylindrical part its skirt. Since both kinds of gas are lighter than air and weight of gas enters the problem, it will be convenient to use absolute pressures per unit area in horizontal sections. And since numbers are banned, let

a = atmospheric pressure
w = unit weight of the deck in the same unit
s = equivalent unit weight of the unbuoyed portion of the skirt
u = uplift pressure of the gas in contact with the deck
d = downward pressure of the gas in contact with the water
h = height of the gas column between water and deck
g = weight of gas in a unit column = kh(u + d) where k is a constant.
x = weight of water in a unit column as high as the inside-outside difference in levels.

1. We have u = a + w + s. As the tank goes up, a and w are unchanged, but the skirt rises in the water, reducing buoyancy and increasing s. Therefore u, the gas pressure at the top, goes UP.
2. The sump is a cylindrical hole. The ones I've seen are only partly underground — probably just far enough to reach a solid foundation for the invert of the tank.
3. The downward pressure of the gas in contact with the water is the upward pressure on the deck plus the weight of the gas column between, or d = u + kh(u + d) = a + w + s + kh(u + d). The downward pressure on the water outside the skirt is a. So the inside-outside difference in water levels x = d − a = w + s + kh(u + d). So when the barometer drops, reducing a, x remains unchanged. However, for a gas at constant temperature and mass, PV = C, that is, pressure times volume is constant. Now u and d each include a and diminish, so in the term kh(u + d) which remains constant, h must increase. This makes the hood tank go up. So subpart A is *UP* and subpart B is *unchanged*.
4. No.
5. No.
6. Poets described a city's slums as, "the other side of the railroad tracks and down by the vinegar works," but if the city had a gas holder, that's where the real slum was. Input gas filtered thru the water as a scrubber, polluting the water with sulfide and the less volatile hydrocarbons. An intolerable environment for a penthouse. Also the fire hazard makes it unsuitable for either penthouse or heliport; and for the latter, lightning rods around the hood would be hazards on a foggy night.
7. It might be possible to design an "elastic" escalator — but prohibitively expensive for the low traffic volume.
8. I never heard of the water freezing in a gas holder. The large volume of enclosed water must remain at a fairly constant temperature. The seal water between skirt and outer tank might freeze thin at the surface but not solid enough to retard a rotating skirt.
9. This is a question of both economic and prudent design. A utility facility should have a reasonably comfortable margin for peak demands and future growth. If the holder reached its top limit, I think the manager would wish it was 10 feet bigger. I doubt that there is a considerable hazard of overdesign; when you see a gas holder you probably see a plantation of them. As for the gas company profiting on evaporation loss, No, not any more than it profits on other inefficiencies inherent in the system. The customer is billed for the volume passing thru his meter at a rate set by a public utilities commission adjusted for the B.t.u rating and periodically revised to allow the company a limited return on its capital investment (known as its rate base).
10. Practically the same answer here, but the margin is more important. If in part 9 the holder reached the top, the inlet valve could be closed; but if it reached the bottom, irate customers would be eating cold cuts and inconvenienced by pilot lights going out. As for a corrosion check, cathodic protection could reverse galvanic action so that there would be a harmless encrustation instead of corrosion.
11. Why does Quilter want to know all these things? Is he writing a book? Or going into the gas business?

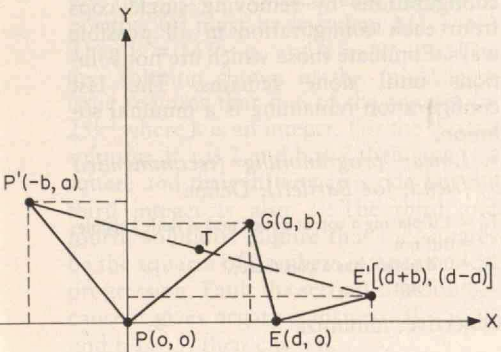
Also solved by Jack Parsons, William J. Butler, Jr., Joseph G. Haubrich, Gerald Blum, Richard I. Hess, and Thomas F. Snyder.

JUN 4 An M.I.T. student bought a treasure map from an old sea captain who told him the coordinates of the small island on which the treasure was buried. The map showed a palm tree, a eucalyptus tree, and an old wooden gallows. The instructions said to walk from the gallows to the palm tree, counting the number of steps. At the palm, turn right by a right angle and take the same number of steps, placing a stake in the ground at the point reached. Start again at the gallows and

walk to the eucalyptus, counting the number of steps. At the eucalyptus turn left by a right angle and take the same number of steps, placing a stake at the point reached. The treasure is to be found buried half way between the two stakes. The sea captain told the student that the old gallows had completely disappeared, having rotted away; but the trees still stood. The student is attempting to devise a method for locating the treasure. Can you help him?

The key, of course, is that the location of the gallows is immaterial. Carl M. King submitted the following:

The information given will find the treasure, beginning at any arbitrary location of the gallows. The sketch shows the construction. The only measurement of significance is the distance (d) between the palm tree and the eucalyptus tree.



	Coordinates	
	x	y
P = palm tree	0	0
E = eucalyptus tree	d	0
G = gallows	a	b
P′ = first stake	−b	a
E′ = second stake	(d + b)	(d − a)
T = treasure	½ d	½ d

Using arbitrary coordinates for the gallows, G(a, b), you carry out the construction. When you calculate the coordinates of the mid-point between points P′ and E′, you obtain a result that is independent of the coordinates of point G.

The coordinates of T (treasure) are [(d + b − b)/2, (d − a + a)/2], for which x = d/2 and y = d/2. Isn't that surprising?

Also solved by Harry Zaremba, Claude Rabache, Robert Pogoff, Russell A. Nahigian, Raymond Gaillard, James N. Cawse, Richard S. Galik, Jack F. Parson, John T. and/or Janet M. Rule, Christian P. Marchand, Glen Ferri, T. H. Greenway, Neil E. Hopkins, Judith Q. Longyear, William Benton Fisher, Daniel E. Feldman, Jim Toker, Joel Tepper, Chip Lawrence, Paul Mailman, E. Jamin, Ken Kiesel, Jeff Kenton, W. A. Schoenfeld, Richard I. Hess, Gerald Blum, William J. Butler, Jr., R. Robinson Rowe, and the proposer, John E. Prussing.

JUN 5 Given any collection of straight streets $S_1, S_2, \ldots, S_K$ intersecting at points

$I_1, I_2, \ldots, I_n$, describe a general method of finding the placement of a minimum number of policemen so that every intersection can be seen by at least one policeman.

The following solution, consisting of three methods of increasing sophistication, was submitted by Richard I. Hess:

1. *Explicit enumeration:* Try all ways of placing m cops at the n intersections starting with m = 1, then m = 2, m = 3, etc., until a lowest m achieves a condition where each intersection is visible.

2. *Implicit enumeration or branch-and-bound:* Put a cop at each of the intersections; obviously they can see all intersections. Now consider removing a cop from each intersection in turn and remove from consideration all configurations which don't allow visibility of all intersections. Repeat this process of creating more configurations by removing single cops from each configuration in all possible ways. Eliminate those which are not solutions until none remains. The last configuration remaining is a minimal solution.

3. *Linear programming (recommended by friend, Joe Bartlett):* Define:

$T_{ij} = 1$ if placing a cop at node i makes node j visible;
$\quad = 0$ if not.
$A_i = 0$ if node i has a cop there;
$\quad = 1$ if not

Objective: minimize

$$X = \sum_{i=1}^{n} A_i .$$

Subject to

$$C_i = \sum_{j=1}^{n} T_{ij} A_j > 0 \text{ for all } i = 1, 2, \ldots, n$$

$$A_i \geq 0 \text{ for all } i = 1, 2, \ldots, n$$

This problem can be solved by standard linear programming methods.

Method 3 was also proposed by Hal Vose, and other responses were received from R. Robinson Rowe, William J. Butler, Jr., Dr. and/or Mrs. Zoltan Cs. Mester, and Joseph G. Haubrich.

Better Late Than Never

DEC 1 and DEC 2 Emmet J. Duffy has responded.

JAN 1 John M. Rand has responded.

M/A 2 Raymond Gaillard and E. Jamin have responded.

M/A 3 Eric Jamin, Lt. Col. Douglas H. Merkle, and John T. and/or Janet M. Rule have responded.

M/A 4 Gerald Blum, Winslow Hartford, Ken Kiesel, William R. Knowlton, Ralph Menkoff, Peter Ross, R. Robinson Rowe, and John Woolston.

M/A 5 Gerald Blum, Guy F. Boucher, Gregory C. Daley, Winslow Hartford, Ken Kiesel, R. Robinson Rowe, John Woolston, Raymond Gaillard and John T. and/or Janet M. Rule have responded. Emmet J. Duffy does not care for the published solution, which he says is not a gen-

eral one. He suggests:
To find three distinct positive integers such that the sum of any two is a square, take any three different squares whose sum is even, with the largest square less than the sum of the other two. Subtract the largest square from the sum of the other two and divide by 2 to obtain one integer. Subtract this integer from each of the two smaller squares to obtain the other two integers. For example, take 64, 144, and 196 as the three squares. Then $(64 + 144 - 196)/2 = 6$; $64 - 6 = 58$; $144 - 6 = 138$. The trio 6, 58, 138 cannot be found by any of the published methods. Let a, b, c be the three integers and M^2, N^2, O^2 be the squares in ascending order. Let $a + b = M^2$, $a + c = N^2$ and $b + c = O^2$. Then $2a + 2b + 2c = M^2 + N^2 + O^2$. Hence the sum of the squares must be given. Solving for a, we find that $a = (M^2 + N^2 - O^2)/2$. Hence for a to be positive O^2 must be less than $M^2 + N^2$. Then $b = M^2 - a$, and $c = N^2 - a$. The first solution shown in the July/August issue requires that one of the squares be $25k^2$ where k is an integer. For the second solution, if a is 2 and b is 7 their sum is a square and their difference is odd but the third integer is also 2. The third and fourth solutions require that the squares be the squares of numbers in arithmetical progression. Fault the second solution because it gives negative answers. If a is 10 and b is 15, then c is -6.

MAY SD 1 Jack Parsons disclaims responsibility, and Emmet J. Duffy and William J. Butler feel that the probability is greater than 7/16.

May 3 E. Jamin has responded.

Proposor's Solutions to Speed Problems

SD 1 There are seven 31-day months of the 12 in a year. The only aliquot parts of 12 are 2, 3, 4, and 6. No subset of the seven is spaced at two-, three-, or four-month intervals and only one subset {January, July} is spaced at a six-month interval. Therefore, they last met in July and will meet again next month.

SD 2

$$\begin{array}{r} 11 \\ 1 \\ 1 \\ \underline{1} \\ 14 \end{array}$$

[They saw this on TV so it must be o.k.-Ed.]

Allan J. Gottlieb, who studied mathematics at M.I.T. (S.B. 1967) and Brandeis (A.M., 1968, Ph.D. 1973), is Assistant Professor of Mathematics at York College of the City University of New York. Send problems, solutions, and comments to him at the Department of Mathematics, York College, 150-14 Jamaica Avenue, Jamaica, N.Y., 11432.

An Institute Informant

The Editors' digest of recent and current concerns at the Massachusetts Institute of Technology

Seeking Life on Mars

No one expects to find the "little green men" of science fiction, and many scientists doubt that the dry Martian environment can harbor life of any kind. But the search for traces of living things is high in the priorities for the two Viking spacecraft which will land on Mars during the summer of 1976.

Even though present conditions there are unpromising, Mariner spacecraft observations suggest that water may have been far more plentiful on Mars in that planet's geologic past. If life as we know it ever existed there, organic compounds in the Martian atmosphere will be among its artifacts. Accordingly, the Viking Molecular Analysis Team, led by Professor Klaus Biemann of M.I.T., has devised a tiny, remote-controlled analytical chemical laboratory to identify even minute quantities of organic materials. Samples of the Martian atmosphere and surface material will be brought into the Viking and heated. Organic materials (if any), vaporizing at lower temperatures than inorganic ones, will be drawn into a gas chromatograph and, when separated, into a mass spectrometer for identification. Results will be telemetered to earth.

Direct evidence of living things is the goal of the Viking Active Biology Team, of which M.I.T. Professor Alexander Rich is a principal member. Martian soil brought into the Viking will be exposed to carbon dioxide containing radioactive carbon; another soil sample will be exposed to potential foods — sugars and amino acids — containing radioactive carbon. If any of the radioactivity from either experiment is transferred into the soil, or if the atmosphere above the soil samples changes, then some form of transpiring living material will be assumed.

No one at M.I.T. associated with the Viking experiments will be disappointed by negative results; and at least one planetologist — Professor Ronald G. Prinn of the M.I.T. Department of Meterology — is on record with such a prediction. This is because the Martian atmosphere — at least today — is very thin, rich in carbon dioxide but poor in oxygen. Since there is no atmospheric protection such as earth's ozone layer, the Martian surface receives a steady downpour of deadly radiation. "From a scientific viewpoint," he says, "there is almost no basis for life on Mars."

Professor Klaus Biemann who leads the Viking Molecular Analysis Team is an expert in separating and identifying organic chemicals. He and his team have devised an automatic chemical laboratory now aboard the Mars-bound Viking spacecraft which will seek such materials — possible evidence for Martian life now or in the past — in the atmosphere and soil of the "red" planet.

Shedding Light Slowly on the "J" Particle

How does a major scientific discovery move from private to public knowledge? Ambigously.

Two letters in *Science* this fall describe how M.I.T. Professor Samuel C. C. Ting and his colleagues came to publish the first report of the puzzling new "J" particle *(see February, 1975, pp. 59-60)*.

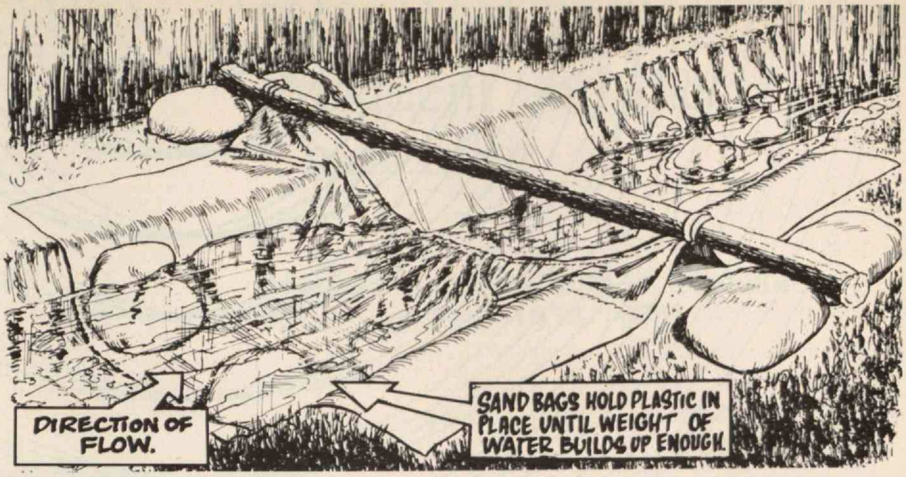
The crucial experiment was conducted at Brookhaven National Laboratory at the end of August. By mid-October, just before an M.I.T. symposium in honor of Professor Victor F. Weisskopf *(see February, pp. 58-59)*, the results were certain: there was "a sharp peak" in particle production when protons bombarded a proton target at exactly 3.1 billion electron bolts. But Professor Ting tried to contain himself during the symposium ("we had quite a few discussions, in which we disclosed our discovery," but there was no general announcement) because he hoped soon to clarify some questions of interpretation.

A week later Professor Ulrich Becker, who was working with Professor Ting, reported the "J" particle results at an M.I.T. seminar; but Professor Martin Deutsch, Director of the Laboratory for Nuclear Science under whose auspices Professor Ting's group was working, thinks "the presentation was so cautious that the full significance . . . did not become clear to most participants" — including Professor Deutsch himself until he had a private discussion after the meeting.

But gossip will out; Professor Ting's conversations during the Weisskopf seminar led by the end of October to a "flood of inquiries," including a rumor in Brookhaven that the Ting group was planning a champagne party. Professor Deutsch began to urge prompt disclosure, and he now apologizes to some colleagues with whom he was less-than-fully communicative at a cocktail party at the end of October.

So it was that on November 6 Professor Ting visited the Editor of *Physical Review Letters* and, upon finding that action appropriate, "wrote a simple draft." Four days later, at Stanford, he was told of the similar but more recent finding by a Stanford-University of California group using the Stanford Linear Accelerator; they called it a "psi" particle, and both reports appeared similtaneously in mid-November.

Two men can install this simple dam in a small stream in about an hour; its purpose is to provide a deeper channel in a sedimented stream, thus restoring that stream to use by alewives.



Highways for Alewives

A sheet of plastic 10 by 20 feet, 20 feet of stout line, eight grommets, and eight tie-down stakes — the simple recipe for a fish ladder which, when multiplied by scores or even hundreds, could make dozens of New England streams home once more to the ubiquitous alewife.

(For readers whose education in New England nature lore has been deficient: the alewife is a plump, silvery fish which is itself edible but it usually considered valuable as food for commercially exploited North Atlantic fish. Like Pacific salmon, alewives return from the sea to the rivers of their birth to spawn, and the "herring" run is a sure sign of New England's tardy spring.)

The problem, of course, is that many New England streams in which alewives once bred are now diverted or silty, and fewer and fewer streams offer sufficient water flow for spawning alewives. So the alewife population is falling, and with it the food supply for such valuable fish as cod and haddock.

Concerned to restore shallow streams to their original roles as alewife runs, Robert W. Day and John W. Zahradnik of the Aquacultural Engineering Department of the University of Massachusetts and Arthur B. Clifton of the M.I.T. Sea Grant Program have joined to design a simple fish ladder. The illustration (*above*) shows how it works, and for detailed instructions readers may write for Report No. MITSG 75-6 JUM from the M.I.T. Sea Grant Program, Room 1-211, M.I.T., Cambridge. There is also a 12-minute, 8-mm. movie available for group showings.

Five Pressure Points and a Campus Mood of Enthusiasm, Tautness

What are the pressure points for university administrators in the year 1975?

If M.I.T. is typical, there are five — as listed by President Jerome B. Wiesner and Chancellor Paul E. Gray in their 1975 annual report to the M.I.T. Corporation:

— The need to trim budgets without sacrificing creativity and quality in teaching and research.

— The search for additional resources — in M.I.T.'s case a $225 million Leadership Campaign to be completed by 1980.

— The evaluation and development of new programs in areas of new importance.

— The continued challenge of shaping undergraduate programs "to meet the new needs of new generations of students."

— The quest for equal opportunity in education and employment for women and minorities.

These pressure points are widely shared, and the problems they represent well understood by faculty and students. As a result, say President Wiesner and Chancellor Gray, the campus mood is "a mixture of enthusiasm and tautness. . . . The tensions brought about by financial pressures, after years of social pressures and turmoil, are clearly growing, introducing concerns which drain energies from creative activities."

M.I.T.'s task — it has already begun — is to learn "to live in a new period in which rapid growth cannot be maintained, but in which the same kind of vitality and change that come easily with apparently unlimited growth are especially needed.

"Now they must come more from inner resources, intellectual and financial. And they do," say Dr. Wiesner and Dr. Gray, "but not without considerable discomfort."

Two Strategies for Capping Oil Prices

What economic and political strategies will assure for the U.S. ample supplies of petroleum at realistic prices?

Two views from two members of the M.I.T. faculty:

Morris A. Adelman, Professor of Economics, calls for a major change in the relationship between the U.S. as buyer and the O.P.E.C. nations as exporters: secret, competitive bidding among exporters for the privilege of selling oil (*see "Foreign Oil: a Political-Economic Problem," March/April, 1974, pp. 42-47*).

Sidney S. Alexander, Professor of Management and Economics in the Sloan School of Management, has an even simpler answer. The oil market behaves just like any other: as supply goes up, price goes down; his proposal, therefore, is for the U.S. to take whatever action it can to encourage increases in oil production anywhere in the world.

The point of Professor Adelman's plan for a U.S. sale of oil-import licenses is to force competition among O.P.E.C. nations where there is none now. Those who doubt its wisdom say that the O.P.E.C. cartel is strong enough to set a price and stick with it, holding that no O.P.E.C. nation would sell at a lower price behind another's back. But Professor Adelman foresees — even without U.S. government efforts to nourish seeds of suspicion, which he would not oppose — "a constant, divisive . . . haggling over market shares" among oil-rich lands.

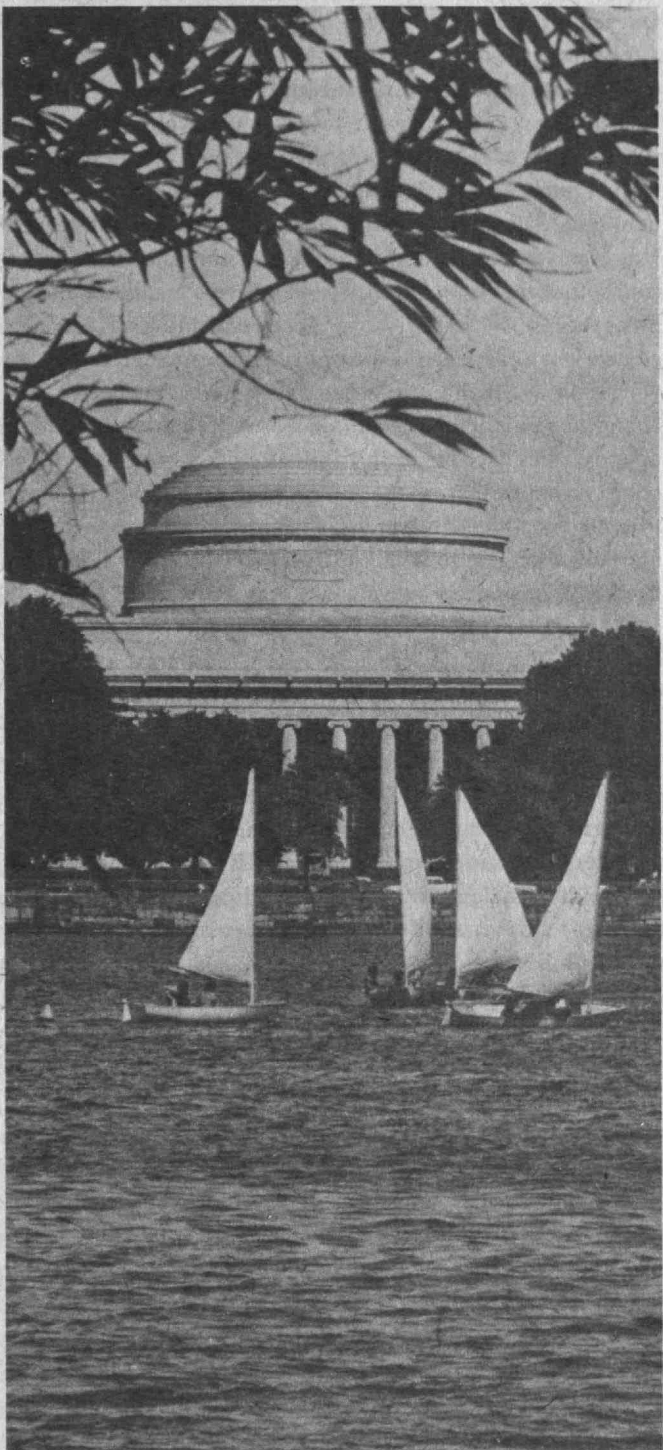
Professor Alexander's argument rests on simple international economics. The O.P.E.C. nations are spending money in the developed countries almost as fast as their oil exports generate credits in those countries, and they need our goods and services. In this situation, alternatives which threaten to reduce our dependence on O.P.E.C. will have the effect of reducing O.P.E.C. prices because the exporters will want to assure their market.

That means Alaskan development, offshore oil development, and any other economical supply strategies we can devise. . .

. . . Such as, for example, trading our agricultural exports to the U.S.S.R. for the privilege of sending U.S. crews to exploit Siberian oil. U.S. oil exploration technology is the most advanced in the world; we could bring Soviet oil into production faster and at less cost than the Russians can. Taking the long, broad view of the world market, whether new oil comes from Russia, Alaska, the North Sea, or Saudi Arabia will matter not at all: the effect will be to reduce world oil prices.

Report of the President and the Chancellor

Massachusetts Institute of Technology Academic Year 1974-1975



M.I.T. is alive and well, though not without its problems. A glance through out past annual Reports reveals that we have seen each recent year as a new and perhaps increasing challenge — a mixture of constraints and opportunities, some self-generated but most a reflection of conditions in the country itself. One wonders in passing if each year *is* increasingly a challenge or whether, as we muse in these Reports, we should not reach for a better word to describe the rapidly changing state of the Institute and the society in which it functions.

These are, to be sure, troubled times, and the conjunction of recession, inflation, the diminution of trust, and a general sense of social malaise are causing strains in most institutions and organizations, M.I.T. included. But there have been challenging times before in the history of the Institute — moments when even its very survival seemed to be in doubt — such as in the aftermath of the Civil War and in the severe depression of the 1870s. The Institute has lived through many times when the society seemed confused and drifting; it has emerged from each of these periods basically stronger and better prepared to carry on its work. Frequently such times have been moments of great opportunity as well as anxiety for they usually involved a rediscovery of the essence of the Institute.

We should take heart from the outcome of those earlier periods as we strive to maintain and add to M.I.T.'s special strengths, and to encourage the development of those activities and attitudes that will make M.I.T. a vital and important place in the future. Such efforts require not the reactive stance which is implied by the word "challenge" but a positive vision of the leadership role that an institution like M.I.T. should play in the education of bright and concerned young men and women, in the exploration of new realms of theory and practice, and in the cooperative evolution of an increasingly responsive and humane society. At a time when the newspapers carry stories on cities on the verge of bankruptcy, universities in serious financial straits, many people in fear of job loss, and belt-tightening in virtually every domain, talk of visions of a rosy future may seem quixotic in the extreme. But vision is precisely what is needed, for only a well-articulated view of what the future *could be* gives focus and heart to the efforts to get from here to there.

The components of our vision for M.I.T. have been

discussed in many contexts — continued intellectual excellence, outstanding departments and programs, responsiveness to major technical and socio-technical needs of our world-wide society, the encouraging of warmth and responsiveness as well as analytic precision in our students, and the achievement of fairness, equity, and respect among all of us who work and study here. The affirmation of that vision, well-grounded in the current life of the Institute and played out in the daily activities of hundreds of people — faculty, students, and staff alike, is the fundamental theme of this year's Report.

In recent annual Reports we have examined M.I.T.'s teaching and research activities in relation to the technical, social and economic milieu and stressed especially our belief in the potential for learning and growth inherent in the American society. We also discussed the need to develop and wisely use new technology to help satisfy many growing needs such as food, raw materials, energy, environmental protection, housing, and health care. We described M.I.T.'s strong efforts to understand and to help moderate the nation's problems both through its traditional roles in teaching and research, and through substantial efforts to align M.I.T.'s own processes and community relationships with current societal objectives.

At the same time a less positive theme has run through our recent Reports, the ever more painful effort to keep the Institute's budget from running away and the many new tasks and constraints — affirmative action, control of information to insure privacy, occupational safety, regulations affecting the laboratory use of animals, controls on human experimentation, etc. — imposed in addition to older, more familiar ones. Together these trends have placed increasingly heavy pressures and workloads on everyone in the Institute — those men and women who provide vital support services, secretaries, administrators, faculty, researchers, students, and especially department chairmen — adding greatly to the strain that would in any event be inherent in a rapidly evolving academic program. In the Reports of our colleagues, the Deans, Vice Presidents, Department Heads, and Laboratory Directors, there is much reference to the stresses that come from trying to do more with less. The constraints are real; in some cases externally imposed, in other cases self-imposed. But mingled in these same reports are imaginative ways to actually achieve more with less, accounts of rigorous examination of priorities and newly emerging areas of growth and development.

The resulting mood on the campus is hard to define. In fact, the mood varies greatly from time to time, area to area, and individual to individual. It can perhaps be described as a mixture of enthusiasm and tautness. The overall thrust remains forward looking, creative, and hopeful. But the tensions brought about by fiscal pressures, after years of social pressures and turmoil, are clearly growing, introducing concerns which drain energies from creative activities. These drains are not unique to M.I.T. In fact, though pressures may be as great at the Institute as elsewhere, the consequent unhappiness appears to be less so — perhaps due to the purposefulness of the M.I.T. programs.

Next year, as we continue the essential efforts to control the financial picture, we intend to give special attention to ways of moderating the resulting tensions, particularly those created by the increasing administrative demands upon individuals' time. The Institute is learning to live in a new period in which rapid growth cannot be maintained, but in which the same kind of vitality and change that come easily with apparently unlimited growth are especially needed. Now they must come more from inner resources, intellectual and financial — and they do, but not without considerable discomfort.

M.I.T.'s programs continue to appeal to students. Undergraduate and graduate student enrollments have risen this year, as have applications for next year in both categories. There were approximately 145 more freshmen in the Class of 1978 (a total of 1,040) than in the previous year when the class was unusually small because of dormitory space limitations. One hundred and ten more graduate students were also in attendance in spite of the shortage of funds for fellowships and teaching and research assistantships.

In last year's Report we reviewed the evolution over the past 15 years of M.I.T.'s undergraduate education. This year we had hoped to do a similar review of what had happened to graduate education at M.I.T. during the same period. However, we soon became aware that neither the data nor the conceptualizations to do a thorough job were readily available. Since the last formal review of graduate education was conducted nearly ten years ago — when Federal support for graduate education was perhaps near its peak — there has been much change in terms of financial support, research interests, career opportunities (academic institutions, industry, and government), composition of the graduate student body (fellows, teaching assistants, research assistants, minorities, women, non-U.S. citizens) to name just some of the dimensions that need to be examined actively.

Since the rapid expansion of the Graduate School paralleled the expansion of research both on the campus and in the country more generally, there is a need for a deeper understanding of how this expansion reflects the state of the several fields and what influence basic and mission-oriented research have had in each instance. During this same period there has come about a fairly drastic increase in the postdoctoral population; hence the structure of the basic M.I.T. "learning family" — faculty, undergraduate and graduate students, postdoctoral fellows and other research associates in addition to technical support of personnel — has changed quite considerably.

Finally there is a need to understand better the changing cost of graduate education as well as the changing social environment of graduate students. We feel sufficiently the need to gain a deeper understanding of this entire complex of issues that we propose — at this propitious moment when Professor Kenneth R. Wadleigh has just become Dean of the Graduate School — to have a group of faculty and administration study this area during the current academic year. We hope to report our findings next year at this time.

Some of the trends in undergraduate education, as discussed in last year's Report, continue. The great interest in health careers is sustained as indicated by the fact that 186 men and women applied to medical schools from M.I.T. this past

year, 115 were seniors and the rest alumni and juniors. This emphasis has placed a heavy teaching load on the Department of Biology and created an increased, but not yet troublesome, demand for some chemistry subjects. At the same time, there is a substantial decline in law as a career among M.I.T. students, no doubt reflecting the fact that job opportunities for recent law school graduates are less available than they were a few years ago.

Perhaps the most important trend to emerge in recent years is the increasing fraction of the undergraduate student body choosing one of the engineering options, reversing a decline that had persisted for a number of prior years. Approximately 45 percent of this year's sophomores who designated a major are enrolled in the School of Engineering. This brings the total undergraduate enrollment in engineering to 44 percent for the Classes of '76, '77, and '78, up from 36 percent in 1971-72. There is no obvious reason, perhaps not even a single reason for this welcome development. We know that the nationwide decline in engineering enrollments has stopped, no doubt due to the relatively better employment prospects that engineering enjoys at this moment compared to many other careers, but the resurgence of student interest in the engineering professions appears to be more pronounced at M.I.T. than elsewhere.

We would like to believe that renewed student interest in engineering as a career is a reflection of the School's own efforts at renewal and its rededication to furthering the evolution of the engineering profession in response to broadened professional scope, including the engineering sciences and technologies, the process of engineering (i.e., the conception and development of reliable and economical technical solutions) and the process of planning responsible uses of technology.

The growing conflict between the many new opportunities for teaching and research that were developing and the mounting financial pressures and resulting budget reductions in the departments caused the Dean of Engineering, Alfred A.H. Keil, to seek and obtain the participation of the School's faculty and staff in a comprehensive process of self-appraisal. The objective of this effort was to identify alternative courses of action which would assure the quality and meaningfulness — the greatness — as well as the financial viability of the School. A number of panels, each with assigned responsibilities, and a coordinating committee consisting of the chairmen of these panels were established. In all, more than 100 members of the School's faculty and staff were involved in the process. The panels have now completed their work and have submitted their reports. These reports, which contain upwards of 50 recommendations, are being synthesized into a final report to be distributed to the faculty early in the 1975-76 academic year. The recommendations in the report deal with issues such as the academic and administrative structure of the School, the School's planning and budgeting process, the academic calendar, approaches to new educational and research programs for the School, and financial and student administrative processes.

One recommendation which may well have importance for other parts of the Institute was the introduction of a program planning and budgeting process which would permit the integration of individual program elements in terms of priority, intensity, and cost. In order to deal responsibly with both the constraints of financial pressures and new opportunities for advancing the School's teaching and research programs, the School of Engineering has actually begun the implementation of this recommendation with the preparation of the budget for fiscal year 1976. Preliminary discussions of the other recommendations have occurred already at Engineering Council and further discussions with the Council and the School's faculty are anticipated for the fall.

A major turning point appears to have been reached in the long effort to create a humanities and arts program for M.I.T. that simultaneously reflects the humanistic goals of a liberal education — the values, historical insights, and cognitive styles that it seeks to make one sensitive to — and still links sufficiently to the modern world of engineering and science. Several developments contribute to this sense of movement. The new Institute Requirement in the Humanities, Arts, and Social Sciences approved by the faculty in spring, 1974, and reported last year, is off to a good start judging by student and faculty reactions. The new arrangement provides students with a much broader range of choices for their electives in this category in the freshman and sophomore years. At the same time, it takes the almost overwhelming load off the few subjects that formerly were allowed to satisfy the Humanities Requirement.

The communications gap between the humanities, broadly construed, and science and engineering has been a perennial issue and recent efforts to bridge the gap between these "cultures" are most promising. The experimental *Technology Studies Program* is an important illustration of such an effort. During the past year Technology Studies was transformed from a set of good intentions into an academic program of research projects, colloquia, and planning for undergraduate and graduate subjects to be offered in 1975-76. The primary emphasis is on the historical, social, and political dimensions of science and engineering — anchoring the intellectual work simultaneously in specific scientific and technological content and in a disciplined understanding of the social change which often attends technical progress. Although the Program's purview includes such diverse disciplines as history, anthropology, sociology, art history, and education, it is focused on increasing our understanding of the role of values in the planning of research, the acceptance, rejection, and use of innovation, the formation of technological communities, and changes which take place in larger communities as a result of technological developments. Another group, chaired by Professor Elting Morison, has proposed the creation of a major center for examining the problems of a technological society in their humanistic dimensions, examining the influences of science and technology on contemporary civilization as well as their historical roots and their implications for the future. Both undergraduate and graduate students would be associated with these activities, together with postdoctoral fellows and Senior Lecturers who

have had a wide range of experience dealing with these problems. The *Concourse Program,* an alternative route for freshmen, is perhaps the most ambitious ongoing M.I.T. effort to unify the intellectual disciplines represented in the first year. In this program, which accepts approximately 50 first-year students, the humanities and science subjects are taught in an integrated manner by a group of faculty members drawn from the Schools of Engineering, Science, and Humanities and Social Science. Finally, a new *Oral History Program* focusing on science and technology has been established. Many of the great figures of contemporary science and technology have been associated with M.I.T. and for many years we have hoped to document their perceptions of the major events in which they have been a part. This new program will, at least in part, prevent the future loss of priceless historical accounts. Equally important, it will provide students with opportunities to merge an interest in history and science.

While serious revitalizing efforts are taking place in the Institute's basic programs, we also can report continued progress in four newer programs which are natural outgrowths of the interests of M.I.T. faculty and students in conjunction with major contemporary issues — the Harvard-M.I.T. Program in Health Sciences and Technology, the Center for Cancer Research, the Energy Laboratory, and the Division for Study and Research in Education. The Program in Health Sciences and Technology has achieved a milestone in the graduation of its first class. The 25 students admitted for the M.D. part of the Program in 1971, finished in June of the past year. The Program continues to grow and develop and now involves 100 medical students of whom 20 percent are concurrently enrolled for both the M.D. and Ph.D. degrees. The new curriculum, as envisioned at the beginning, has been developed to permit deeper penetration of the physical sciences and engineering into medicine. A spectrum of academic offerings, previously not available, is under way or under development. The special subjects developed and taught for students in the Program are also available to other students, especially the many M.I.T. students interested in health careers or biomedical engineering.

The Program is in the process of establishing medical engineering departments or centers at the Harvard Medical School teaching hospitals to further collaborative efforts between medical staffs and engineers. These departments, like hospital departments of surgery, pathology, etc., will provide new training opportunities for students and represent the recognition of medical engineering as a significant medical profession. The Program has, as anticipated, also facilitated collaborative research involving interdisciplinary teams — physicians, engineers, scientists — from Harvard Medical School, its teaching hospitals, and M.I.T. These research projects range from fundamental science to clinical evaluation in human beings. Research programs currently under way or being planned include biomaterials science, cancer radiation therapy, rehabilitation engineering, a biomedical engineering center, and studies of the health effects of energy production.

The Center for Cancer Research, begun two years ago, has grown in size and complexity to the point where it now includes some 70 researchers — faculty, students, and professional staff, mostly from the Department of Biology — and occupies specially designed facilities in the Seeley G. Mudd Building which was dedicated in March. The basic research is addressed toward the understanding, diagnosing, and treating of cancer. Experimental research now includes, in addition to work on animal cells and on isolated cells in cultures, research of a fundamental and diagnostic nature on material from hospital patients, particularly on leukemia.

The Center's research is organized in three groups: 1) the Virology Group which is concerned with RNA tumor viruses and with adenoviruses; 2) the Cellular and Developmental Biology Group which studies the process of mutation, changes in cellular membrane protein, and the abnormal expression of various genes in cancer cells; and 3) the Immunology Group which concentrates on studies of specific antigens on cancer cells, on the structure of the antibody molecules involved in the rejection, and on the development of immunological response.

This Center is well on the way to being a major national resource in the understanding of cancer, providing the opportunity for faculty and students from a number of research groups and departments to work together on a major biological and medical venture.

During the past year the Energy Laboratory, now completing its second year of operation, increased its visibility and viability as the focal point of energy-related research at M.I.T. There has been a clarification and delineation of the research areas of the Laboratory, and funding levels have risen appreciably. The Laboratory is now managed as four units with specific research interests: 1) Energy Management and Economics Studies; 2) Nuclear, Environmental and Electric Power Studies; 3) Fossil Fuel Research; and 4) Special Programs - (small new efforts, end-use technology, alternate energy technology).

Though the Laboratory is still in a developmental stage, it now has a key role in energy-related activities at M.I.T., and its associated faculty and staff members have made significant contributions to the formulation of national energy plans through both technical advice and policy-related studies. Currently some 55 faculty members from ten departments and all five schools are involved, together with 85 students and 45 technical staff members in a relatively open and effective learning environment in close articulation with other Institute activities.

During the past year an advisory board of energy experts from outside M.I.T. has been established. This board reviews the work of the Laboratory on a periodic basis and brings close working knowledge of energy problems to bear in advising the Laboratory on its current programs and future plans.

The year 1974-75 was also the second year of operation for the Division for Study and Research in Education, another effort to increase the options and opportunities of faculty and students. The D.S.R.E. has a pioneering and difficult role at M.I.T., attempting to develop a research and teaching program in the field of learning based upon M.I.T.'s many special competences (for example, the programs in the brain sciences, linguistics, computers and artificial intelligence),

Brain research is being performed as part of the Program in Health Sciences and Technology.

and related as well to the particular problems of a specialized learning environment such as that at M.I.T. The expectation is to provide a focal point for research and teaching which will contribute to the deep understanding of learning processes in individuals and groups and thus hopefully point the way to more effective educational methods. Administratively, we are seeking to achieve the advantages of an academic department and an interdisciplinary laboratory.

The Division offered a number of regular subjects and seminars during the fall and spring semesters which enabled the graduate students associated with the Division to obtain a broad introduction to its areas of specialization. These subjects also served as electives for undergraduate and graduate students from other parts of the Institute. Eight graduate students were involved in an interdisciplinary Ph.D. program administered by the Division in collaboration with other M.I.T. departments. The number is expected to be approximately 12 next year. In addition, the Division is cooperating in a new Master of Science Program with emphasis on science and education.

* * * * *

Within the general context of a forward momentum pressing against financial and social constraints there were, as in every year, particular events which by their extraordinary nature deserve special mention. Some are academic, others the result of events in the world around us. We select a few each year for special mention to highlight scientific or technological milestones, to demonstrate the complexity of the world in which the Institute now lives, and to call attention to those new elements which are likely to be part of the intellectual and social history of the Institute for some time to come.

'J' PARTICLE

One of the Institute's great strengths is the extent to which faculty and students are involved in extending our understanding of basic science. Fundamental curiosity about the origins of the universe, the nature of matter, the origins of life, and why it all works the way it does, absorbs the energies of many at the Institute today, as earlier versions of those same questions puzzled our forbearers throughout mankind's history. The work continues day by day and occasionally, and often unpredictably, a major breakthrough occurs. One such occurred this year with the simultaneous and spectacular discovery, at the Brookhaven National Laboratory and Stanford Linear Accelerator Center, of a new kind of elementary subnuclear particle — the 'J' Particle. Professor Samuel C. C. Ting of M.I.T.'s Laboratory for Nuclear Science headed the team of M.I.T. and Brookhaven physicists which found the particle in the course of a systematic search for such phenomena while bombarding a stationary proton target with protons. The 'J' Particle is the first in a series of new and unexpected particles whose properties still elude classification. Its discovery presents a major challenge to theorists in the effort to explain just what the 'J' Particle is.

On November 27, a special convocation was held at the Institute to hear Professor Ting describe his discovery. At that time, Professor Victor Weisskopf described the immediate reaction of the physics community as follows:

> Some say it may be a new type of meson carrying a new quantum number called 'charm' by some physicists. Others say it may be the carrier of the weak interaction force within the proton that holds it together. It is most probably not a quark. It just doesn't have the right properties... I subscribe at this time to the statement that it is as yet something completely mysterious coming to us from the world of the subnucleus and nobody knows what it is.

ALCATOR

The Alcator high density plasma experiment has come to fruition during the past year. After several years of construction and debugging, this unique M.I.T. contribution to the U.S. efforts to understand the confinement of highly ionized plasmas and ultimately how to derive energy from nuclear fusion reactions is now working extremely well. By taking advantage of cryogenic techniques, and other specialized knowledge existing at the Francis Bitter National Magnet Laboratory and elsewhere at M.I.T., it has been

possible to build a machine which advanced the art in several important aspects. The machine operates reliably at extremely high magnetic fields over a wide range of current densities and for relatively long confinement times, and has achieved a denser plasma than any other fusion machine of its kind. Among its kind of device, Alcator is now one of the most promising and interesting in the world and experiments with it are having considerable impact on the U.S. plasma confinement program.

ALUMNI SURVEY

An important part of M.I.T.'s educational and research mission involves its alumni. We always have sought a strong and mutually rewarding partnership with our graduates. In a time of changing expectations and increased demands on educational institutions, we feel an increasing pull to involve alumni in the life and work of M.I.T. To begin a renewed effort in this direction, we conducted last year, a major survey of alumni views and attitudes about the Institute. The Survey consisted of extensive open-ended telephone interviews of a randomly selected sample of several hundred, stratified to be representative of undergraduate and graduate alumni of all ages. The results were remarkable for the scope and richness of alumni opinion and caring about the Institute which they revealed. The findings speak to alumni as individuals, to the M.I.T. Alumni Association as an organization, and to those of us who seek to guide the Institute in its fundamental academic mission.

What we heard first and foremost from our alumni was the view that an M.I.T. education cannot be matched. Most alumni were quick to say that there is no other place like this, and that if they were of college age, they would come to M.I.T. again for the knowledge, the prestige, and the value of learning how to work hard. At the same time, there were some questions raised by alumni about the impact of M.I.T. on their lives while they were students here — the personal cost of living in what some described as an extremely competitive or austere environment — a pressure-cooker which left too little time for personal growth and the development of a larger perspective. In that sense, some alumni felt that they may have paid too high a price for the M.I.T. degree.

This concern, which also is voiced by some of today's students, leads us to ask whether we can identify and moderate or remove those experiences which tend to detract from, rather than enhance, the quality of the education our students receive here. We must continue to grapple with this question — to make the living and learning environment of the campus as educationally and personally fulfilling as possible.

Another insight we gained from the Survey was that while there was a great deal of support among alumni for the developments in educational and research programs — and a strong interest in M.I.T. — alumni generally knew relatively little about what goes on at the Institute today. It seems clear that most alumni still view the Institute through the eyes of their experience here as students. While they may speak of M.I.T. as a dynamic, changing institution, most of them continue to hold to the image of their own years on campus.

Is there any way that we can supplement this powerful, attitude-shaping experience, rooted in the past, with a current understanding that will enable alumni to carry with them a living portrait of M.I.T.? Obviously, this is a very important matter to us. For, to a large extent, in the eyes of the world, M.I.T. is and will continue to be what alumni think and say it is.

The only sure way to know the M.I.T. of today is to be a part of it. Many alumni — as individuals — have stayed close to the campus by participating in programs and activities at the heart of the Institute, such as serving on visiting committees, screening prospective students, and providing leadership for the Alumni Fund.

The question before us now is how to expand the opportunity for these and many more close ties and working relationships. One obvious area, of course, would be a program of alumni education. We have tried for years to define the educational needs of alumni, but without great success. Perhaps we have had too narrow a model of what lifelong learning might be. In addition to the traditional courses and seminar programs, perhaps we need to invent new models. Some of these may be worked into the new communications programs organized by the Alumni Association under the leadership of James A. Champy, its new Executive Vice President. Other programs might be collaborative activities which bring together alumni, faculty, and students in partnerships where the roles of the teacher and the learner are flexible and interchangeable, depending on the nature of the activity

that brings them together.

At any rate, it seems clear to us that the most meaningful involvements of alumni with the Institute will develop when we find more ways to bring alumni into the life and work of the faculty and students who are here today. We hope to be able to report on significant progress in this area soon.

INTERNATIONAL PROGRAMS

For many years M.I.T. has been an international institution. Our programs have benefited from the participation of exceptionally able students from virtually every country in the world, and our foreign alumni now carry increasingly important responsibilities in their homelands. M.I.T.'s faculty members tend to be international in their professional and scholarly orientation and as a result, research projects at the Institute frequently have substantial international implications. The Institute also from time to time has joined in efforts to develop new institutions in other countries. During the past year, substantial projects were undertaken in Iran and in Venezuela. Important contributions of capital were made by several Japanese organizations. Research projects in Brazil and Europe developed in prior years have been continued and the feasibility of M.I.T. working with alumni and others in Spain on the development of a new institution there has been under consideration.

In undertaking any of these international activities, the interests of those faculty members who would be most directly involved in a project have been and will continue to be a major consideration for the Institute. But clearly, concern about the consequences for all those who would be affected, both at M.I.T. and in the country in question, will continue to be an important element in the Institute's consideration of these undertakings. As a result of the growing volume and complexity of M.I.T.'s international activities over recent years and because there is reason to believe the rate of M.I.T.'s activity in this domain may accelerate, we have asked Professor William F. Pounds, Dean of the Sloan School of Management, to be responsible for coordinating M.I.T.'s various international activities. During the year we named an ad hoc advisory committee of faculty and students chaired by Professor C.P. Kindleberger to review the process whereby M.I.T. undertakes international institutional commitments, including especially the process used in connection with a special program developed by the Department of Nuclear Engineering in Iran, and to recommend to us any changes in that process which the Committee believes would be in the best long-term interest of the Institute. The Committee will report its recommendations during the coming fall term.

PHASE II, BOSTON SCHOOL DESEGREGATION

As the academic year drew to a close, M.I.T. was asked to lend its talents to the amelioration of yet another kind of social problem. In mid-May, Federal Court Judge W. Arthur Garrity issued the so-called "Phase II" desegregation order for the Boston Public Schools, one part of which required the School Department to seek the help of area colleges, universities, and businesses in developing a more diverse array of educational programs through which young people in Boston might voluntarily choose schools outside their local neighborhood, thereby increasing the racial diversity in each school. Each of 22 colleges and universities was "paired" with a school or school district; the specific request to the Institute was to work with the School Department to develop a city-wide "magnet" technical high school and a city-wide "magnet" technical middle school (grades 6-8) in schools located in the neighborhood of East Boston.

This was an unexpected request and we explored it very carefully. It is clear that we are being asked to help with an *educational* task for which we have some competence but little experience, and intertwined with that task is a social issue which is highly controversial. After considerable discussion and consultation during the summer months it became clear that involvement in this task would provide an opportunity for those M.I.T. faculty, students, and staff who wished to participate in an effort with considerable learning potential for all participants; that new funds could be sought to defray the costs of such participation; and that there was, in fact, a feeling on the part of many at M.I.T. that this was an important commitment for the Institute to make. We have therefore embarked on a year-long planning process in collaboration with the Boston School Department.

There are, as always, different views within M.I.T. about how large in scale the effort should be, what educational style is most appropriate for schools of this type, what technical subjects are wisest to recommend when the students will enter the job market several years from now, etc. Discussion of such issues is sometimes heated and we think that is a good sign. This is a project which captures the interest of significant numbers of people at the Institute and the diversity of views is an accurate reflection of the diversity within M.I.T. — diversity which has always been a very considerable strength. We believe that in addition to providing a different range of public service opportunities and contexts for learning, the issues which the project raises are very close to the basic intellectual purposes of the Institute and engagement with them should provide considerable intellectual return to M.I.T. itself.

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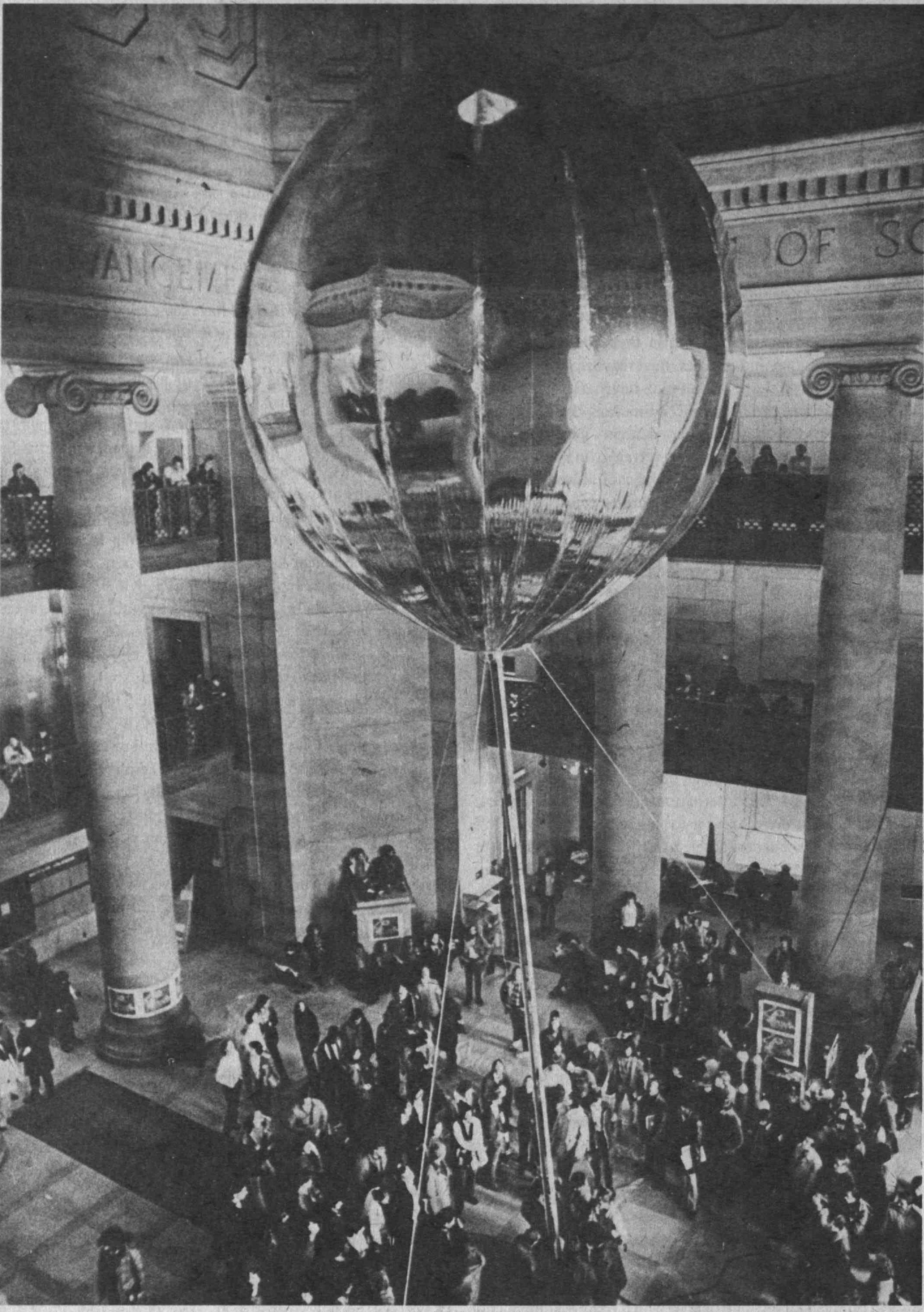
During the past few years the Institute has had continuing concern for the objectives and processes of affirmative action. This phrase has come to include essentially all aspects of the task of equalizing opportunities in education and employment for minorities and women, and of increasing their representation on the faculty, in other areas of employment at M.I.T., and in the fields and professions for which we prepare students. It is ironic that this effort reaches its peak of urgency at just the time when universities are experiencing pressures from other quarters that are more intense than at any time since the Second World War. The devastating impact of



inflation and the difficulties of obtaining support for the new intellectual ventures which we must undertake if we are to remain true to our charter and our potential, combine to make this a difficult time for the social change implied by the objectives of affirmative action.

We could not have predicted the severity of these pressures on us. Nevertheless, the following paragraphs from the Institute's Affirmative Action Plan express accurately now, as they did in 1973, our commitment:

> As a major educational institution, a large-scale employer, and an influence on our society through its students, its alumni, and its employees, the Institute stands committed to the principle of equality of opportunity in employment and in education.
>
> In its most elementary and comprehensive form, our adherence to the concept of equality of opportunity requires that we strive toward a condition in which considerations of race, sex, national origin, and religion are irrelevant as determinants of the access an individual has to opportunities for education, for employment, for achievement, and for personal fulfillment. Rather, the controlling factors in all such matters must be individual ability, interest, and merit ...
>
> While the Institute is obliged, as a major Federal contractor, to develop and sustain a program of Affirmative Action, our commitment to these matters transcends legal or contractual requirements. We undertake these actions and adopt these policies not because we are required to, but because it is right and proper that we do so.

The question of progress on our commitment has been much on our minds in recent months, and because both of us have long-standing personal interests in these aspects of the social fabric of M.I.T., we take this opportunity to summarize our thinking on these important matters.

Our feelings are mixed. We look to the past with a sense of both satisfaction at the effort expended and frustration at our inability to reach all of our objectives. We look to the future with a blend of optimism and uncertainty. It is clear that the need for affirmative action programs in the form of "crisis measures" will diminish, as educational institutions move toward a new mode of operation in which minorities and women are better represented and in which inequitable barriers are eliminated. It is equally clear, however, that some of the vexing problems and challenges will be with us at least through this decade and perhaps beyond. Affirmative action steps will and must continue to be taken at M.I.T. and in all other American institutions until equality of opportunity is not only an accepted concept but an intrinsic part of the fabric of organizations.

"Cloud One" a weather balloon displayed in the Rogers Lobby, was a joint project of the Center for Advanced Visual Studies and the Department of Electrical Engineering and Computer Science.

At M.I.T. the development of programs specifically aimed at increasing the representation of minorities in the student body began in 1968. At that time we admitted about a dozen black undergraduate applicants, including about six who offered convincing evidence of high motivation and of exceptional academic ability, even though their competitive test scores were not high enough to guarantee admission. While this program was of modest scale, it did have the effect of roughly doubling the number of black Americans in the first-year class. Furthermore, it provided crucial first-hand experience with the problems of educating students whose social backgrounds and prior educational experience differed from the usual first-year class.

Beginning with the 1968 academic year we undertook also extensive recruitment of black applicants for undergraduate admission. As a result of these efforts, the corresponding applicant pool increased more than tenfold: from an average of about 30 in 1968 and prior years to approximately 330. We evaluated most of these applicants outside the usual decision process with the intent of admitting those who, on the basis of our best judgment applied to their records as a whole, appeared to have a good chance of successfully pursuing undergraduate programs at M.I.T.

Those students who seemed likely to benefit from a summer of review and a somewhat more gradual transition to the M.I.T. undergraduate environment were invited to take part in a special summer program which has come to be known as Project Interphase.

Our efforts aimed at increasing the number of minority students who would benefit from an M.I.T. education have evolved to reflect the experience we have gained over the past years. We still aim at admitting all those minority applicants who seem to us to have a good chance of doing well here. Project Interphase has changed in detail and in the balance of its activities; it still provides an important and highly valued way of "letting the clutch out gently" for some of the minority students who come here; and we still engage in widespread recruiting efforts to find those who are both interested and best qualified.

As a result of these efforts, the enrollment of minority students in the first year has grown to 4-6 percent of the class (the corresponding fraction for the black American subgroup is 3-5 percent). There has been no significant increase either in the number of minority applicants or in the admitted subgroup in the past few years. In fact, this fall there is a decline in the number of minority students particularly in the black subgroup, just as there was a decline, reversed in the next year, in 1973. The number of minority applicants appears to be quite sensitive to economic conditions and to the general public perception of the job market for scientists and engineers.

The situation of women in the undergraduate student body has improved in important ways in recent years. There has been considerable growth in the number of women undergraduates, from 2-3 percent of the class in the fifties and early sixties to 15-20 percent in recent years. This growth is due in part to the provision of more housing for women and in part to recruitment efforts in the last two years. Since 1971 women and

men have been admitted on a strictly competitive sex-blind basis.

The pool of young women who might reasonably become applicants for admission here appears to be quite large. Thus, the proportion of the class that is female may increase as we continue to encourage women to view career opportunities in the sciences and in engineering as attractive professional goals.

Efforts to increase the number of minorities among the graduate student population at M.I.T. began in 1968 as well. Because graduate admissions are decentralized, with each of the 23 departments granting graduate degrees responsible for its own process and decisions, it is difficult to generalize about these efforts. In most cases recruitment has centered on widespread mailings of information about the department, and on personal contacts with professional associates at schools having significant minority undergraduate enrollments. Most departments have admitted minority students in straightforward competition with other applicants. Other organizations, such as the Sloan School and the School of Engineering, have participated effectively in national programs directed at increasing the number of minority students in those fields. In addition, a few departments, such as Physics, have developed special graduate programs aimed at minority students who would, without special help, be unlikely to be admitted.

As a result of these efforts, the number of minority students in the Graduate School has increased dramatically — from about 0.5 percent in 1968 to approximately 4 percent in 1974-75. These students are not distributed across the schools and departments in the same proportion as non-minority students. A larger than average fraction are enrolled in the School of Architecture and Planning and a smaller than average fraction are enrolled in the Schools of Science and Engineering.

The number of women in the Graduate School has also increased in recent years. During the period from 1968-75 the proportion of women has doubled, standing now at about 12 percent. This increase is the result both of modest recruitment efforts during the past four years and of an increased consciousness in young women about career opportunities in science-based and engineering fields.

For both minority and female graduate students, financial aid is often a major determinant of the decisions affecting graduate study. Applicants often approach graduate study with a heavy burden of educational debt from their years as undergraduates; many have family responsibilities as well. Consequently, the limited number of first-year tuition scholarships for minority graduate students and the Ida M. Green Fellowships, awarded primarily to women, are of particular importance in these efforts, and more financial resources of these kinds are needed.

With the exception of scholars of oriental origin, very few minority persons or women have served on the M.I.T. faculty until quite recently. While the historical record is not entirely clear in this regard, it appears that there were, in 1968, just three black Americans and fewer than a dozen women in the ranks of the faculty. While these very small numbers are not surprising in fields such as engineering and management (in which the number of doctoral degrees that have gone to women and to blacks has, until this decade, been less than 1 percent) one might have expected a stronger representation of women in the humanities, in the social sciences, and in some of the fields of science.

While our concern with increased opportunities for women and minorities spans the entire range of employment at the Institute, we have placed special emphasis on faculty. The growing numbers of minority and female students at the Institute look for persons of similar background on the faculty both as evidence of a serious and lasting commitment to these issues, and as like-minded associates in an environment which sometimes appears to offer few familiar and comfortable points of reference. Although both the thrust of affirmative action requirements and our own concern for these matters is aimed at developing a society in which racial background and sex are of little consequence in employment and educational opportunity, it is clear that minority and female faculty will be especially needed as models and as mentors for students.

Beyond these considerations, strong representation of women and minorities on the M.I.T. faculty contributes greatly to the richness and diversity of this community. In an educational institution both the expansion of knowledge and the growth and development of individuals depend crucially on personal relationships and associations. In such a setting what one knows and understands, and how one communicates that knowledge is important, but what one *is* matters as well, and we are persuaded that the Institute becomes a stronger, more

effective place as it draws on the full range of human talent and experience.

Our affirmative action efforts in the area of faculty have produced significant changes in the past few years. In 1975 there were 18 black Americans on the faculty. While this number falls well short of the goal we set for ourselves six years ago, it represents solid progress. At the same time the number of women on the faculty has increased to 54, which comes to about 80 percent of our goal. All departments have widened their search for highly qualified individuals and have made special efforts to seek out women and minority candidates. We have, of course, held rigorously to the principle of selecting the best qualified candidate, also recognizing that minority and female candidates frequently bring special and important qualities. We are convinced that these efforts and these appointments have strengthened a faculty which was already among the most distinguished in the world.

These increases in numbers of faculty appointments over the years do not adequately reflect our total effort in seeking out and recruiting faculty, particularly in those fields in which the pools of highly qualified minorities and women are very small. Over the past two years, a number of minorities and women declined firm offers of faculty appointments from various academic departments. Some of these negative decisions came after months of search and patient negotiation. The increase in minority and women faculty came during a period in which there was virtually no growth within the faculty ranks and in which several departments were accomplishing modest reductions in size.

Our record of accomplishment in other employment categories is mixed. While we have met, or come close to meeting, our objectives in the hourly, office-clerical, and exempt areas of employment, we have fallen far short of our objectives in the areas of administrative staff and research staff, particularly with respect to minorities. In the area of research staff the problem is not unlike that of faculty. Until quite recently minorities have been grossly underrepresented in engineering and science, with the result that the relevant pools of qualified persons are small.

PROBLEMS AND OPPORTUNITIES

As we appraise our present situation and look toward the immediate future, several areas of concern, and of opportunity, are evident:

— First, we appear to have reached a plateau in our efforts to increase the number of qualified minority applicants for our undergraduate programs. We now know that the group of minority young people who have the necessary secondary school background in mathematics and science is quite small in comparison with the entire secondary school population, and it may not be possible to attract to the Institute a significantly larger proportion of that group than we do at present. Consequently, future increases in the number of minority students who pursue careers in engineering and in the physical sciences are contingent on the degree to which young people can be informed about opportunities in these fields much earlier — probably in junior high school — and encouraged to study the necessary mathematics and science. Such information and encouragement have, in the larger society, traditionally come from parents and friends, and it is just this influence which is largely absent for minority students as a consequence of the virtual exclusion of minorities from these fields in the past. While it is not clear what role the Institute can play in addressing this problem, we need to be more imaginative in our efforts than just recruiting from the available pool at the high-school level.

— The Institute has always embodied very high standards of performance for members of the faculty. Appointments at all levels and promotions to the senior ranks have been based on effectiveness in teaching and research in a highly competitive environment. Minority and female members of the faculty experience these same pressures for excellence, and strive, as a matter of course, to high standards of personal accomplishment. At the same time, however, these individuals are the objects of a set of pressures that are a direct consequence of their minority and/or female status. They often are prevailed upon to carry committee responsibilities that go well beyond average assignments of this kind,

and these assignments are frequently related to equal opportunity or affirmative action matters. They are invariably sought out by minority and women students who look to them for academic, career, and personal counseling and for succor and evidence of familiar stability in an unfamiliar, sometimes uncongenial, environment. Out of a deep sense of duty most minority and women faculty undertake tutoring and counseling responsibilities that go well beyond either the expectations or the examples of their professional colleagues. Finally, they function in a society in which the residual minutiae of racism and sexism often represent a persistent grating distraction. Thus, while the needs of professional growth and development represent a significant challenge to essentially all young members of university faculties in the present climate of retrenchment, the task is doubly difficult for most of our female and minority colleagues. We have an obligation to be understanding of these pressures and to provide a supportive and sympathetic environment. Several departments address these concerns by insuring that every junior faculty colleague has a senior mentor, who can provide advice and counsel; the central administration has tried to provide a sympathetic ear and to build sufficient support structures for women and minorities.

— It has been clear for some time that some minority members of the M.I.T. community doubt the sincerity and durability of our commitment to affirmative action in employment and education, and that these doubts arise, at least in part, because no black or other minority person serves in a senior position of line responsibility in the administration. There can be no assurance that this situation will change in the near future. Budgetary pressures have caused us to undertake a careful review of all administrative functions and our interest must remain focused on the trimming of functions and on the consolidation of responsibilities. In this climate, shared by most other universities, we must make still further efforts to insure that the perspectives of minorities and women are considered in the evolution of Institute policy and practice, particularly in those situations in which they do not currently participate directly.

— The Institute's commitment to the principle of equality of opportunity in education and employment is intended to produce fundamental change in our internal processes and norms. Such change comes about as the cumulative result of significant small changes in most aspects of our mode of operation, and these in turn require adherence to a variety of new policies and procedures. Some of these changes, such as the requirement that every department prepare and keep current a detailed operational affirmative action plan, or the requirement that new appointments be preceded by adequate documented searches for qualified candidates, including minorities and females, are perceived by some department chairmen and administrative officers as undesirable bureaucratic mechanisms which interfere with the primary tasks of making a strong institution greater. There are, of course, substantial risks associated with the internal mechanics of affirmative action. Procedures can outlive their utility and become unproductive bureaucratic encumbrances, and the mechanics of change can become counterproductive if they are allowed to undercut the fundamental importance of individual quality and merit in an academic community. We must remain alert to these hazards and be flexible and willing to adapt the specific procedures of affirmative action programs to change the institution to such a degree that the program is no longer needed — the sooner the better.

These problems and the need to make continued progress toward the objectives for equal opportunity in education and employment that we have set for ourselves are high priority tasks. They compete for attention with the other important tasks which we have mentioned — efforts to trim budgets, the search for additional resources, the development of new programs and organizations in emerging areas of academic interests such an energy and health, and the continuing challenge of shaping our undergraduate programs to meet the needs of new generations of students. All these programs are important to the future of the Institute; no simple linear ranking of priorities is possible. We must make progress simultaneously on all these issues. This we intend to do.

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A most important event of the past academic year was the vote of the Corporation of December 6, 1974, to accept the recommendation of the Corporation Development Committee for a capital campaign that would seek to increase the Institute's endowment for the support of the students and faculty, to provide funds for the continued development of many vital academic and research programs, and to permit the construction of a small number of vitally needed facilities.

Planning for the M.I.T. Leadership Campaign (involving the Chairman and Honorary Chairman of the Corporation, as well as the President, Chancellor, Provost, Vice President for Resource Development, and many other members of the M.I.T. community), gave a special coherence and urgency to last year's review of the Institute's programs and purpose. That review, much more intensive than normal, brought into sharp focus the very special role of M.I.T. in the world of industry, science, and technology and highlighted the many programs at M.I.T. that have relevance to current problems of our society. Our efforts to focus more precisely than is usual on the Institute's special purposes and strengths, its special audiences, friends and sponsors, and on the many vital areas of research in which it is pioneering, made us appreciate afresh the extraordinary world-wide leadership role held by M.I.T. We find in our travels that the M.I.T. style of technical education, broadly defined, its applied research, and its close

links with industry and government are admired and emulated all over the world. We are expected to set the direction and pace for the future; hence the name for this new campaign. The responsibility of living up to the varied expectations placed on M.I.T. is awesome but also inspiring.

The plan to expand the resource base of M.I.T. could hardly have come at a more propitious time, for the extraordinary range of fiscal and social problems now bedeviling the nation are reflected, not surprisingly, on the campus. All operations cost more. The new programs in energy, health, materials and natural resources, and productivity improvement, while financed primarily from the outside, require some continuing Institute funds for their effective development. Existing financial resources, even with their normal growth patterns, would be inadequate to simultaneously meet these two major demands. But the normal growth patterns do not now exist. Endowment values have fallen in recent times and endowment income is down for obvious reasons. Budget cuts and controls based upon strict economies and staff reductions have served to maintain an acceptable — if somewhat pained — financial posture during the past several years despite the major impact of the Draper Laboratory divestment, legally mandated administrative functions, the steep escalation in energy costs, rampant inflation, and the leveling off of funds available for research support. However, these pressures leave little funds for academic initiatives, either needed modernization in existing teaching and research programs, or for the newly initiated programs.

The Leadership Campaign, with its dual emphasis on the support of faculty through endowment and program development, will insure the dynamism of the current efforts, and at the same time add to the financial foundations of the Institute so that it can remain a vigorous, independent institution during the turbulent years that lie ahead. It will require much attention of the senior officers in the years ahead but it is a commitment of time that we believe is essential to the continued vitality and well-being of M.I.T.

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IN SPECIAL RECOGNITION

The individual efforts and distinctions on the part of the faculty at M.I.T. have been many during the past year. Four members of the faculty were elected to membership in the National Academy of Sciences; ten members were elected to the National Academy of Engineering; and seven were elected to membership in the American Academy of Arts and Sciences. These elections, and numerous other honors and awards, attest to the continued high quality of the M.I.T. faculty and to the dedication of its individual members to scholarship of the highest order.

Of special note during the year were the appointments of three members of the faculty to the distinguished rank of Institute Professor: Dr. Morris Cohen, Professor of Metallurgy; Professor Walter A. Rosenblith, Provost; and Dr. Ascher H. Shapiro, Ford Professor of Engineering. Dr. Cohen was additionally honored as the third recipient of the James R. Killian Faculty Achievement Award.

The past year saw several appointments to senior posts that should receive special mention. Professor Bruce Mazlish was appointed Head of the Department of Humanities and Professor Norman C. Rasmussen, Head of the Department of Nuclear Engineering. In addition, several laboratories and centers at the Institute came under new leadership during 1974-75. Professor Otto Piene was appointed Director of the Center for Advanced Visual Studies; Professor Benson R. Snyder, Director of the Division for Study and Research in Education; Professor Arthur P. Solomon, Director of the Harvard-M.I.T. Joint Center for Urban Studies; Dr. Myron Tribus, Director of the Center for Advanced Engineering Studies; and Professor Patrick H. Winston, Director of the Artificial Intelligence Laboratory.

Several new appointments to senior administrative positions also should receive special mention. Dr. Thomas F. Jones was appointed Vice President for Research upon the retirement of Professor Albert G. Hill; Jay K. Lucker was appointed Director of Libraries upon the retirement of Natalie N. Nicholson; Glenn P. Strehle was elected Treasurer of the Corporation upon the retirement of Joseph J. Snyder; Dr. Kenneth R. Wadleigh was appointed Dean of the Graduate School upon the retirement of Professor Irwin W. Sizer; and Frank Urbanowski has been named Director of the M.I.T. Press.

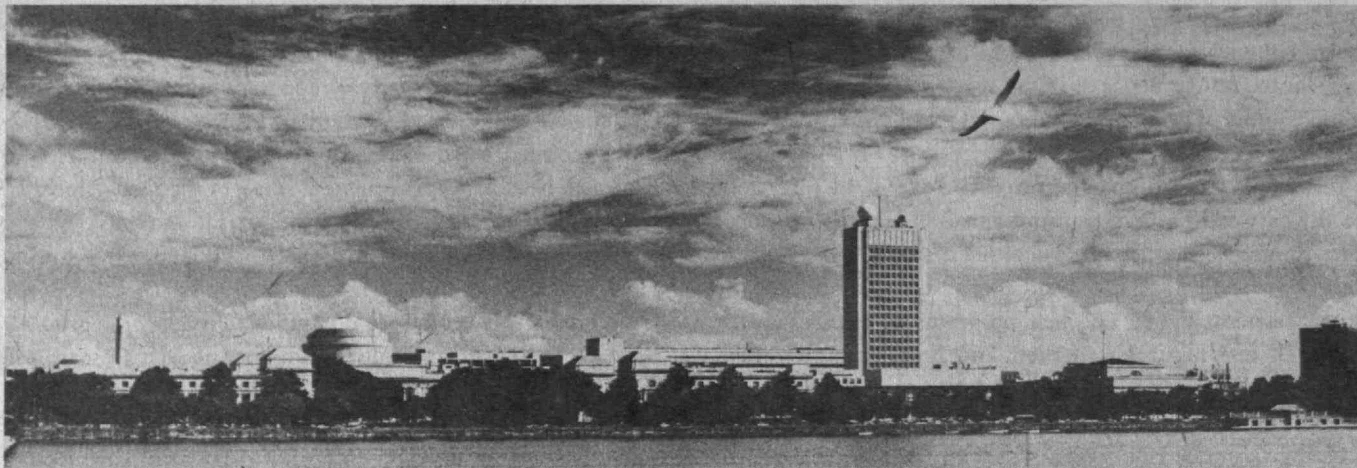
The past year also marked the retirement of eight distinguished members of the faculty. Their years of service to the Institute and to their students will long be remembered and appreciated. They are Associate Dean Sanborn C. Brown, Professor in the Department of Physics; Professor Harold A. Freeman, Department of Economics; Professor Robert J. Hansen, Department of Civil Engineering; Professor Albert G. Hill, Department of Physics; Assistant Professor Benjamin R. Martin, Jr., Department of Athletics; Elting E. Morison, Elizabeth and James Killian Class of 1926 Professor, School of Humanities and Social Sciences; Professor Irwin W. Sizer, Department of Biology; and Professor Prescott A. Smith, Department of Mechanical Engineering.

Of particular sadness to us during the year were the untimely deaths of several respected colleagues and advisors.

James M. Barker, Life Member of the Corporation, died in July, 1974, after a long illness. During his nearly 40 years of service in the Institute's governing body he served as a wise and spirited advisor. As student, former staff member in civil engineering, counselor and friend to five M.I.T. Presidents, and as a leader in alumni affairs, he played a major role in the life of the Institute.

Bradley Dewey, Life Member of the Corporation, died in October, 1974. Member of the Class of 1909, he was a pioneer in the development and use of synthetic rubber, a distinguished chemical engineer and a leader in the U.S. chemical industry. His interest in the life and development of the Institute was a cource of unflagging strength.

William D. Coolidge, a distinguished inventor who developed the modern X-ray tube and the ductile tungsten



filament used in electric lightbulbs, died in February, 1975. Member of the Class of 1896, Dr. Coolidge went on to a long and distinguished career, of which the Institute is proud to have been a part.

Antoine M. Gaudin, Richards Professor Emeritus of Mineral Engineering, died in August, 1974, following a long illness. He was an internationally recognized pioneer in the field of process metallurgy, distinguished especially by his research on uranium recovery. Dr. Gaudin joined the M.I.T. faculty in 1939, serving as mentor and advisor to generations of students and younger faculty members until his retirement in 1966.

Warren K. Lewis, Professor Emeritus of Chemical Engineering, died in March, 1975. Regarded as the father of modern chemcial engineering, Professor Lewis was known to generations of M.I.T. students as a hard-driving teacher in the adversary tradition, tempered by a soft heart and a rich stock of funny stories. Among his students many have become members of the M.I.T. faculty and distinguished scientists; his influence on all of us and on the Institute has been deeply felt.

William H. McAdams, a pioneer in the field of chemical engineering and Professor Emeritus of Chemical Engineering, died in May, 1975. Together with the late Professors William H. Walker and Warren K. Lewis, Professor McAdams was instrumental in the development of chemical engineering as a distinct discipline.

Major General James McCormack (USAF, Ret.), who served M.I.T. as Vice President for Industrial and Governmental Relations, died in January, 1975. A distinguished public servant, he served with distinction in a variety of crucial posts in a period of rapid change in science and technology.

These men have been outstanding examples of strength and dedication to science and technology in the service of humanity; they will be remembered and honored by generations of their students, friends, and associates.

Jerome B. Wiesner, *President*
Paul E. Gray, *Chancellor*

October 3, 1975

STATISTICS FOR THE YEAR

The following paragraphs report briefly on the various aspects of the Institute's activities and operations during 1974-75.

REGISTRATION

In 1974-75, student enrollment was 8,050, an increase of 162 over the 7,888 enrolled in 1973-74. This total was comprised of 4,136 undergraduate and 3,914 graduate students.

Graduate students who entered M.I.T. last year held degrees from 336 colleges and universities, 210 American and 126 foreign. The foreign student population was 1,412, representing 18 percent of the total enrolled. The foreign students were citizens of 93 countries.

Degrees awarded by the Institute in 1974-75 included 1,027 bachelor's degrees, 856 master's degrees, 107 engineer's degrees, 362 doctoral degrees — a total of 2,352.

The number of women at M.I.T., both graduate and undergraduate, has increased continuously. In 1974-75, there were 1,111 women students at the Institute, compared with 921 in 1973-74. In September, 1974, 211 first-year women entered M.I.T., representing 20 percent of the entering class. In 1974-75, a total of 232 degrees were awarded to women.

STUDENT FINANCIAL AID

During 1974-75, the student financial aid program was characterized by significant increases in total awards, in loans made, and in the amount of scholarship assistance. The number of individuals assisted increased for the first time in four years.

A total of 1,791 undergraduates who demonstrated the need for assistance (44 percent of the enrollment) received $3,582,814 in scholarship aid and $2,192,268 in loans. The total of $5,775,082 represented an 18 percent increase in direct aid over last year.

Scholarship assistance was provided by the scholarship endowment in the amount of $1,918,629, by outside gifts for

scholarships in the amount of $531,162, by direct grants to needy students totaling $617,442, and by scholarship assistance from M.I.T.'s own operating funds in the amount of $376,840. The special program of scholarship aid to minority group students represented an additional $138,741 from specially designated funds. An additional 390 students received direct grants from outside agencies, irrespective of need, in the amount of $854,738. Outside scholarship support thus totaled $2,003,342, a substantial increase over last year's total. A significant portion of the increase was again due to increased funding of the Federal government's grant-aid program. The undergraduate scholarship endowment was increased significantly by the addition of $1,019,408 in new funds, which raised the principal of the endowment to $22,003,115.

Loans totaling $2,192,268 were made to needy undergraduates. Of this amount $591,073 came from the Technology Loan Fund, $1,592,195 from the National Defense Loan Fund, and the remainder from other M.I.T. loan funds. An additional $400,713 was obtained by undergraduates from state administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained $999,729 from the Technology Loan Fund. Of this total, $410,670 was loaned under the Guaranteed Loan Program and qualified for Federal interest subsidies and guarantees. In addition, graduate students borrowed $76,160 from the National Direct Student Loan Program. The total loaned by M.I.T. to both graduate and undergraduate students was $3,268,157, an increase of $531,824 over last year's total.

CAREER PLANNING AND PLACEMENT

In spite of the continuing recession, the Institute's graduates found their talents generally in demand. Their good fortune intrigued newspaper reporters covering the employment market for college graduates. Hearing about the job offers received by M.I.T. students, they would contrast this with the bleak picture they had been given at other colleges. Then they would reflect a moment and say: "Ah, but M.I.T., of course, is different."

It is a measure of the Institute's reputation that the number of employers coming to interview in the Career Planning and Placement Office rose slightly over the year before. More firms came recruiting than in any year since 1969-70. There was also an increase in recruiting activity at the Sloan School. Salaries paid to graduates in engineering about kept pace with the cost of living, a significant phenomenon in the economic climate that has prevailed for the last few years. The most handsomely rewarded member of the senior class was a chemical engineer who went to work for an oil company in Saudi Arabia. Salaries paid to Sloan graduates rose less sharply than salaries in engineering, but a Sloan degree still held its own as a prized credential.

Demand for Ph.D. degree candidates in fields other than engineering was less strong. The data on the June class still needs to be sorted and analyzed to see how the Ph.D.s in individual fields fared in the job market.

Considerable attention was given during the year to helping students in architecture. Informal statistics released in April by the American Institute of Architects put the unemployment rate among professional architects at 25 percent. Students in architecture are fully aware of the economic realities, but for many, architecture is the one profession worth pursuing and they will gladly accept any job as a stop gap if it will keep them in touch with the profession. The Career Planning and Placement Office hopes to add a part-time staff member in 1975-76 to expand its help to students in architecture, planning, humanities, and the social sciences.

The Office, in conjunction with the Office of the Dean for Student Affairs, offered a seminar in the fall term in which undergraduates visited professionals at their place of work. The seminar was particularly intended to help students see at first hand the kinds of career opportunity for which M.I.T. offers preparation. The seminar attracted a small but enthusiastic class, including some upperclassmen as well as freshmen, and is being offered again in 1975-76.

The recession made itself felt in the area of alumni placement. The number of alumni registering with the Office rose appreciably, to some 620 from 557 the previous year, and the number of job vacancies reported to the Office fell significantly. Many registrants said that they had not had to look for a job since they graduated, sometimes 20 years ago. A large portion of staff time was devoted to counseling on career alternatives and approaches to job hunting.

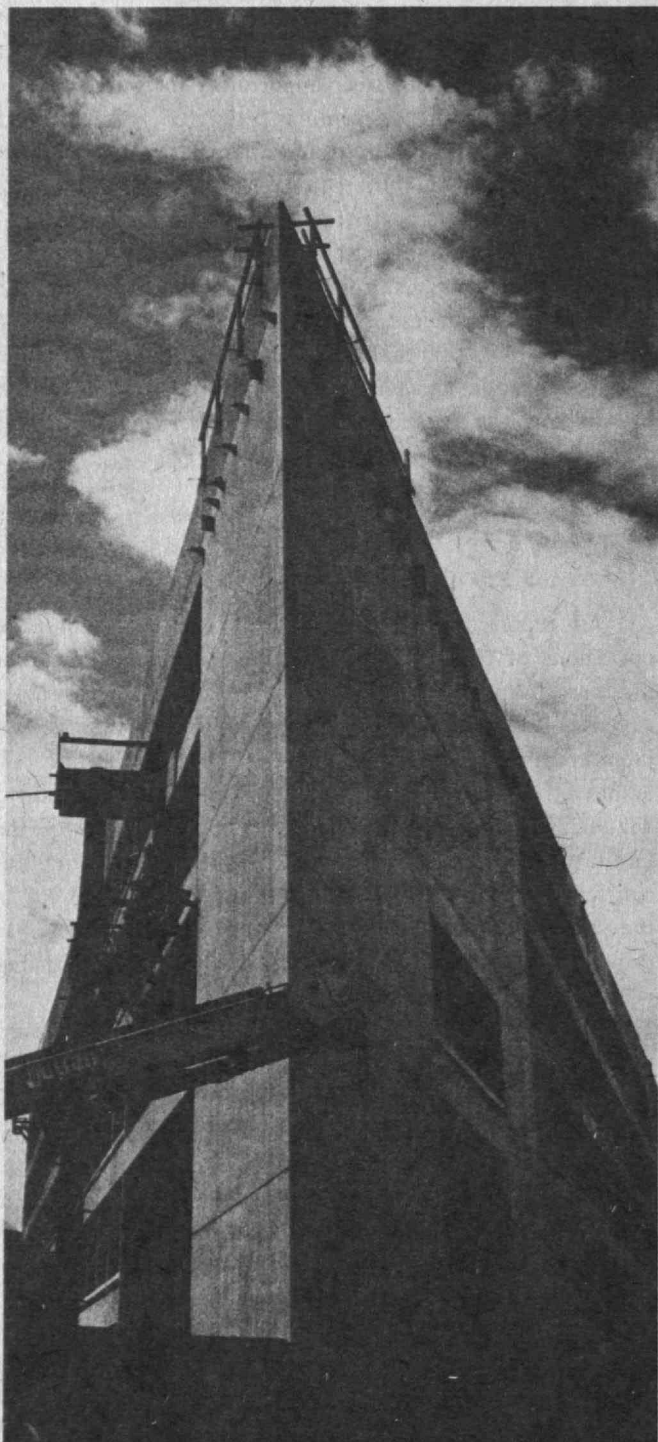
FINANCES

As reported by the Treasurer, the total financial operations of the Institute, including sponsored research, increased from the level of 1973-74. Educational and general expenses — excluding the direct expenses of departmental and interdepartmental research, and the Lincoln Laboratory — amounted to $92,860,000 during 1974-75, compared to $82,962,000 in 1973-74. Reflected in the finances of the Institute was the decrease in the use in operations of unrestricted funds to $4,596,000, compared with $5,309,000 in the preceding year. In addition, the Research Reserve was drawn on in 1974-75 in the amount of $480,000, compared with $2,781,000 in 1973-74.

The direct expenses of general departmental and interdepartmental sponsored research increased from $59,436,000 to $64,992,000, and the direct expenses of major laboratories and special departmental research decreased from $76,989,000 to $74,084,000.

The construction program of the Institute continued to make progress in 1974-75, with the book value of educational plant facilities increasing from $190,029,000 to $197,500,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, had a book value of $340,038,000 and a market value of $402,491,000. This compares to book and market totals of $340,866,000 and $388,176,000 last year.



GIFTS

Gifts, grants, and bequests to M.I.T. from private donors decreased from $21,406,000 in fiscal year 1973-74 to $20,282,000 in fiscal year 1974-75. The latter figure includes unrestricted direct gifts to the Alumni Fund of $715,000, which constituted part of the total of $3,327,000 reported by the Alumni Fund in 1974-75.

PHYSICAL PLANT AND CAMPUS ENVIRONMENT

Several phased projects were completed during the year. The renovation of the east wing of Ashdown House for graduate students was completed in August, 1974, in time for the students to move in before the beginning of the fall term; the west wing had been completed the previous November. The Seeley G. Mudd Building, including the Cell Culture Center and the remainder of the Center for Cancer Research, was also finished and occupied during the year.

The George R. Wallace, Jr. Geophysical Laboratory, described as the best equipped geophysical observatory in the world, was dedicated in May, 1975. The underground observatory in Westford, Massachusetts, is capable of detecting earthquakes anywhere in the world. It also will be used to evaluate earthquake risk in New England and to test seismic instruments before being placed on the moon or other planets.

Work progressed during the year on the Chemical Engineering Building, the West Campus undergraduate house, and the installation of Refrigeration Machine No. 4 at the central utilities plant. This 4,000-ton unit brings the central plant refrigeration capacity to 10,500 tons and represents the last of the original central plant programmed units.

The new 300 student undergraduate dormitory on the West Campus, located on Memorial Drive adjacent to MacGregor House, is scheduled for completion in time for occupancy the last week of August, 1975.

* * * * *

The new Chemical Engineering Building is scheduled for completion in December, 1975.

Institute Review

Alumni Officers Conference: Improving Alumni-Institute "Chemistry"

In This Section

The Alumni Officers Conference
In Cambridge to chart their year's work as officers of the Alumni Association, 600 alumni focus on the Institute's communications and professional responsibilities to its graduates (**page 97**).

The Chancellor's Message
Paul E. Gray, '54, describes an undergraduate experience which seeks the elusive combination of professional and personal maturity (**page 100**).

A Coming Crunch on Resources?
On the West Coast, six M.I.T. faculty members express their faith in technology and free markets in the exploitation of resources (**page 102**).

Enter the Class of 1979
At 1,169, the Class of 1979 is M.I.T.'s largest (**page 107**). The freedom of "alternative programs" appeals to some (**page 108**), and a co-ed reports that "it takes all the running you can do to keep in the same place" (**page 109**).

Introducing David Dobos
We've added a "Sports Desk" at *Technology Review*; in his first contribution, its proprietor (he is a junior from Columbus, Ohio, whose major is economics) explores the conflict between M.I.T.'s "participation principle" and that of N.C.A.A. (**page 111**).

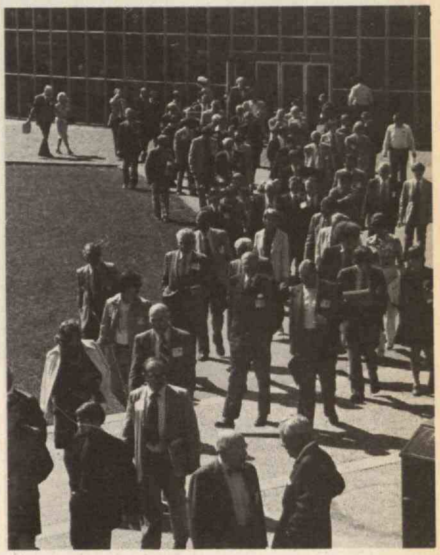
The Nobel Prize
Two scientists who "grabbed the world of biology by the hair, twisted it around, and sent it scurrying down a whole new corridor of thought" share the 1975 Nobel Prize in Medicine and Physiology; David Baltimore was one of them, and he is M.I.T.'s fourth Nobel Laureate (**page 112**).

More than 600 alumni came to Cambridge in September to partake during the Alumni Officers Conference of what Howard W. Johnson, Chairman of the Corporation, calls "the special chemistry that occurs in this place."

But they heard President Jerome B. Wiesner and Vice President Constantine B. Simonides, '57, propose that alumni experience of that "chemistry" is still inadequate — that better opportunities for alumni to understand and share the special strengths of M.I.T. are at the top of the Institute's agenda for the future.

"You are full partners in this educational enterprise," President Wiesner told the alumni officers. "But a larger involvement of alumni in the intellectual work of the Institute is our greatest matter of unfinished business," he said.

What President Wiesner meant was the Institute's continuing frustration with the question of its post-graduate obligations to alumni — how to help alumni through seminars, courses, and other educational tools maintain their professional effectiveness and better understand the world in which they live. Both President Wiesner and James A. Champy, '63, Executive Vice President of the Alumni Association, promised major efforts — "rededication," President Wiesner said — to achieve the elusive goal of "continuing education."



How shall alumni better understand and relate to their alma mater? Key questions for over 600 leaders at the 1975 Alumni Officers Conference; their answers would be key items on the agenda of the Alumni Association, said James A. Champy, '63, Vice President.

Achieving "a Collective Pride"

Reporting on an intensive survey of the attitudes and needs of alumni completed during 1974 (*see March/April, 1975, pp. 74-79*), Mr. Simonides emphasized the same issue of continuing involvement. If the survey's sample was representative, he said, most alumni are enthusiastic about the Institute and convinced of the importance of its work; they are "deeply rooted in the intellectual fiber of the Institute," and they want to maintain that association.

But many graduates, said Mr. Simonides, demonstrated an incomplete knowledge of current M.I.T. activities. "It is clear that most alumni view the Institute in terms of their own images, from their own experience; that we need to improve the effectiveness and efficiency of our communications effort," said Mr Simonides.

When his turn came, Mr. Champy responded with a description of reorganized Alumni Association programs whose goal is to "convert the quiet sense of pride which each of us feels in his own way" into a "sense of collective pride" out of which can be achieved new involvements for alumni everywhere.

Five regional officers will serve all of the interests of alumni in New England, New York, the midwest, the south, and the far

west. A new "tabloid" will report alumni, Institute, and Alumni Association activities through which its graduates are engaged with M.I.T. And there are plans for an intensive review of new Association activities which he pledged will make a "creative response" to the concerns which Mr. Simonides and his associates found. □

Honoring Alumni Presidents

The 81 individuals who have served as presidents of the M.I.T. Alumni Association over the association's 100-year history will be honored soon with the installation of plaques bearing their names on the Mezzanine Corridor under the Great Dome and overlooking MacLaurin Lobby in Bldg. 10.

Howard W. Johnson announced the plan at the 1975 Alumni Officers Conference and said the plaques will be a tribute to the entire association on the occasion of its centennial.

"We have chosen that central location for the plaques to emphasize the central role that alumni leadership has played in M.I.T.'s development, and our gratitude as an institution to those distinguished leaders," he said.

"The central role of alumni leadership in M.I.T." was Howard W. Johnson's theme; he began his welcoming speech (above) to over 600 alumni at the 1975 Alumni Officers Conference by expressing thanks "for all you do, in countless ways, for M.I.T." There followed a series of meetings on how to improve communications between the campus and over 50,000 members of the Alumni Association; informal conversations between alumni and faculty; and explorations of the campus – including a gymnastics exhibition and a sale of pottery by members of the Student Art Association. (Photos: Calvin Campbell)

Student Life: Good-bye Stereotype

Are the emotional and personal costs of an M.I.T. education something to be survived, for the excellent education and career possibilities its reputation can offer? If you have that perception of M.I.T., you are wrong. Student panels from the humanities, science, and engineering schools gave a very different portrait of M.I.T. life to members of the Educational Council at an afternoon session on September 12, just before the 1975 Alumni Officers' Conference.

It was the initial terror of the unknown that everyone remembered to be most difficult. After that, the workload is strenuous. But, "once you're here, M.I.T.'s going to do everything to keep you here. The only problem is getting accepted," one student told Council members.

If M.I.T. did not meet their expectations, the cause was a happy one. The absence of rigidity was impressive, particularly for those students whose educational goals change midway. "When I got here I found that engineering just wasn't what I wanted to do," Cheryl Marceau, '76, explained. "I had taken a lot of science courses in high school, and what I found just wasn't what I had expected. I was surprised to find I could go into a lot of other things." She is now at the Sloan School studying labor relations.

(Continued on page 102)

The Chancellor Calls for a New "Collegial Relationship" Between "Junior and Senior Learners"

A sharp dichotomy in the responses of alumni queried by the 1974 Alumni Survey (see left) *on the subject of their M.I.T. educational experience: there was general and often high enthusiasm for the academic programs and for the professional opportunities which open to students as a result of completing M.I.T. degrees, said Constantine B. Simonides, '57, Vice President of M.I.T., at the Alumni Officers' Conference. But many alumni told survey workers that they remember the Institute as a "pressure cooker," a cold, impersonal place where demands of fast-paced, narrowly focused academic work were so intensive as to leave little time for personal growth.*

". . . I am still capitalizing on what I learned there," said one alumnus. "It was extremely rewarding, but it was not a very happy place to be."

Paul E. Gray, '54, Chancellor, who followed Dr. Simonides to the A.O.C. rostrum, agreed that even present undergraduates continue to see the Institute as a "forbidding, dehumanizing adversary." He then went on to analyze some sources of this frustration and to propose a response in the form of broad changes in the character of teaching programs.

Here are excerpts from Dr. Gray's address:

While I make no claim to full understanding of this complex dilemma, some observations about the causes of alienation seem to me to be pertinent:

First, M.I.T. has been, since its founding in 1862, a science-based institution. The common-denominator here is a serious engagement with the sciences and with their universal language, mathematics. Science as a discipline is predominantly cumulative in nature, in contrast to several of the traditional fields of study in a liberal arts program. The traces of the intellectual development of modern physics, of linear system dynamics, or of control system theory have their roots here in the first-year core subjects and run, in nearly linear fashion, through many subjects and thus several terms. The disciplines of science thus impose a level of structure on one's academic work that is not characteristic of universities or liberal arts colleges generally. The continuity and thoroughness of effort demanded by this structure has much influence on the spirit of the Institute. Sustained high levels of achievement are not just admirable — they are crucial to survival — and there is little room for the academic dilettante, no matter how sparkling and brilliant he or she may be.

Second, the Institute attracts young people who are already exceptionally able. We measure this ability, and determine their admissibility by the record of their earlier achievement. These students have, and we value, *results-oriented achievement.* Many have values that place the development of understanding and competence above the building of those personal skills associated with effective interpersonal relations. It seems to me that many undergraduates come here predisposed to be intense, academically-oriented loners, and for some this predisposition is strongly reinforced by the environment, which rewards academic excellence and which encourages each individual to "do your own thing."

Third, though I am persuaded that the quality of undergraduate instruction at the Institute exceeds, by a considerable margin, that at most universities and all but a few liberal arts colleges, I believe it is true that the faculty of the Institute do not, for the most part, regard the *classroom* instruction of undergraduates as their primary mission, nor do they receive their principal professional satisfaction and recognition from this activity. For most of the faculty, most of the time, formal instruction, such as that which occurs in the lecture hall or classroom, provides neither the intimacy nor the coupling to one's personal intellectual frontiers that are essential to highly effective teaching. If a faculty member's encounter with an undergraduate is centered on mutual intellectual interests and takes place on a scale that encourages sharing, personal relationships of quality and meaning naturally follow.

A *fourth* factor which seems to me to be relevant to these concerns about the quality of life here grows out of the history of our residential arrangements. For most of its history the Institute was essentially nonresidential. As recently as 1948 we provided on-campus housing for less than 700 undergraduates. With the opening of the new West Campus House this fall we house more than 2,200 undergraduates on campus. I believe that the availability of on-campus housing, coupled with the development in the last decade of a vigorous housemaster-tutor program have made a significant difference in the quality of life for undergraduates.

Fifth and finally, the quality of life here is strongly influenced by the dominant ethos of the place, which is widely shared by students and faculty alike. Life at the Institute often proceeds at a frenetic pace. Some would say that we are, collectively, hyperactive. All of us who study and learn and work here must guard against letting ourselves be seduced into single-minded attention to immediate and narrow technical tasks at the expense of human relationships.

In summary, then, those alumni who express concerns about the M.I.T. environment and wish for a climate that places greater value on human relationships, greater responsiveness to individual needs, and more time for exploration of broader horizons, underline an important and persistent issue.

Toward Educational Independence

We can have a positive influence on the quality of life at M.I.T. by improving arrangements such as facilities for on-campus housing. Other recent innovations such as the introduction of the Independent Activities Period and the change to pass-fail grading in the first year to ease the transition to M.I.T. have been beneficial as well. Of course, extracurricular activities, including athletics are important and highly valued by many students.

Nevertheless, it seems to me that significant long-lasting improvement will depend upon effecting a fundamental change in the nature of the educational encounter. Specifically, a major difference would be made by an evolution toward an undergraduate program which relies much more than at present on the development of close collegial relationships between students and faculty, which ask that both learn and grow, and which places such educational encounters at the center of our curricular emphasis.

It seems to me that our central educational purpose can be expressed in relatively simple terms. I believe that we come closest to fulfilling our special role in society when we enroll students who have a deep interest in the sciences, or in those fields that build directly on the sciences, or students who require a real understanding of science and technology to achieve at the highest levels in their fields of endeavor, and when we bring them, as quickly as possible, to the threshold of educational independence. More precisely, our emphasis should be on developing within our undergraduate students, as soon as

Where does Paul E. Gray, '54, Chancellor, do his serious thinking? In this case, on the steps of the Student Center, en route to a speaking engagement in Kresge Auditorium.

they are ready and as fully as we can:
— The capacity for self education,
— The ability to deal effectively with new intellectual situations,
— The ability to synthesize new knowledge in meaningful terms, and
— Independence of formal educational processes.

We must not be satisfied with learning that stops with the acquisition of knowledge and the mastery of the distilled understanding of others. Rather we must insure that the learning of our students encompasses the capacity for creative response to intellectual novelty. In view of the rate of change of technological and scientific knowledge, there is no responsible alternative.

Engaging Students as Colleagues

If we accept this objective as appropriate to our strengths and to the extraordinary capacity of our students, then we should organize our undergraduate educational programs in ways that move us toward this objective as fully and as effectively as possible. This requires, in my view, a clear and substantial change in the *style* of the educational encounter for most of our instructional purposes. Specifically, I believe that we should base more of our instructional effort on one-to-one contact between students and faculty in situations in which they are engaged as colleagues in the search for new knowledge and understanding — situations which permit the intellectual intimacy that fosters learning and inspires teaching. Such situations now arise in thesis work, in some project laboratories and work on special topics, and, quite widely, in the Undergraduate Research Opportunities Program. Our task is to increase the relative occurrence of such intellectual encounters and to make them central to our educational programs rather than peripheral as they are now, at least in terms of degree requirements.

One-to-one encounters engage both students and faculty in significant, deeply-felt associations which satisfy at once the hunger of students to know and the desire of faculty to share their excitement and understanding of their work on the frontiers of knowledge. Such problem-based encounters bring out the very best in our students and in our faculty and build on those strengths which define M.I.T.'s uniqueness.

Work of this kind is intense, fast-paced, and demanding. Nevertheless, it is clear that the close personal relationship between professional colleagues — a junior learner and a senior learner — gives a sense of purpose, meaning, and fulfillment to such work and often gives direction and richness to a student's entire educational experience.

I am suggesting that we place more emphasis, in the structure of our undergraduate programs and in the experiences of our students, on one-to-one associations based on a shared intellectual interest. I believe that this shift in emphasis would have two immediate significant benefits.

First, it would engage a majority of our students in ways that would be attractive and intellectually liberating. Many come here with a vision of personal achievement — of greatness — that is all too often diminished or extinguished by the prescriptive formal rigors of the undergraduate years.

Second, it would engage faculty at the center of their existence by encouraging them to develop intimate collegial relationships with students instead of requiring them to talk *at* students in classrooms three times a week.

In these respects such a curricular emphasis seems to me to build directly on the unique strengths of the Institute. Few other educational institutions have the combination of features that make such a program possible on a wide scale. These features include:
— An eager, able, inquisitive, self-directed student body.
— A faculty of splendid quality, with a tradition of excellence in scholarship and in the creation of new knowledge.
— A rich base of ongoing research activity, supported by high-grade scientific and technical facilities.
— A large complement of research staff members, graduate students, and post-doctoral fellows who are actively engaged in the scholarly activity of the place.
— Extensive linkages to the "real world" for which we prepare students.
— A tradition of flexibility in administration and a climate of trust in administrative leadership.

No massive restructuring of conventional modes of instruction is called for. Rather, this vision of the undergraduate educational encounter requires a small shift in the balance of our current activities, together with an expectation that every undergraduate develop a one-to-one problem-based association with a member of the faculty and build the rest of his or her program around that relationship.

It may indeed be true that not all disciplines or fields of study are amenable to this mode of encounter. Most scientific and technological areas of study are. In any case, we should structure our educational programs to employ the most effective means for the educational task at hand. Some subjects and some learning tasks make optimal use of the lecture-recitation or seminar modes of instruction, and we should continue to employ those modes in those situations.

Finally, it is important to recognize that this proposal is *not* aimed at making researchers of all who taste the apple. It *is* aimed at developing, rapidly and with excitement and satisfaction, the capacity for educational self-sufficiency, which is the basis for intellectual self-renewal.

It seems to me that we now have at M.I.T. the opportunity — indeed, the responsibility — to build a new and more vital educational experience for undergraduates. The strengths on which we build are probably unique to this special place. I believe that development of the educational encounter along lines which rely on one-to-one collegial associations between junior and senior learners is consonant both with our national role in science-based education and with our responsibility to future generations of students.

This feeling of latitude has been fostered by innovations in curriculum. The Independent Activities Period during January was the most exciting for these students. The break in schedule, opportunities to do short-term projects in depth or explore other fields of interest are its highlights. Also, there was the chance to escape their niche on the Charles. "Boston is one of M.I.T.'s assets and I.A.P. gave me the chance to know the city."

But the pressures from the heavy workload in required courses tend to eliminate any sense of freedom during the regular term. One result, said a participant, is that "students won't take courses they're interested in." But the same student had the solution: take seminar courses, which are not as time-consuming.

The many extracurricular activities at M.I.T. — gospel choir, fraternities, sports, radio, student government — were cited as proof that there is time to gain a multidimensional lifestyle. "What you do learn is how to budget your time."

A curiosity to many outside the student environment is the dwindling of student activism, the hallmark of campus life in the '60s. Though the cymbals and tympany have been lost, the underlying meaning of activism has not. "There aren't any big issues like the Viet Nam war. Now students are involved in community projects, like tutoring and high school study programs." Another student added, "I think since that time the administration is much more open. If students want something now they get their ideas together and talk to someone about it."

Coed dorms and the admission of more women has also led to a more "balanced" or "normal" atmosphere. Coed living? asked an alumnus. No big thing, replied a student. If there are problems, they are so few that there's no need to change the whole system because of them. And there are many different living arrangements to choose from.

So instead of a vast, impersonal superstructure, to these students M.I.T. is a little like home; but with a lot more to do. — *S.F.*

The Materials Challenge: Technology's Special Arena for Dealing with Risk

"The principal arena of technology," says Howard W. Johnson, Chairman of the Corporation, "is the conversion of natural resources to man's service." And vice versa, too: though social, political, and environmental controversies arise in every debate on the use and management of resources, technology is the decisive issue.

So technology itself, acting in concert with political and management expertise, becomes a major resource, said Mr. Johnson in his keynote address to a "natural resources conference" sponsored by the M.I.T. Club of Northern California in San Francisco on September 25.

George P. Shultz, Ph.D. '49, former Secretary of Labor and of the Treasury who is now Vice President of Bechtel Corp., went one step further by describing M.I.T. as itself "one of the country's unique resources," where "the notion of turning ideas into solution is a hallmark."

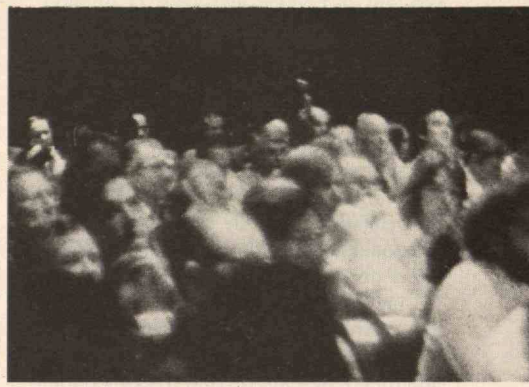
All six conference speakers — members of the M.I.T. faculty — made clear the increasing interplay of technological and social issues in the exploitation of natural resources. Wisdom in such interrelated issues of technology and policy — basically, reliance on the market system as we know it to set our technical priorities and evaluate their usefulness — will assure that there need be no "doomsday" when resources are literally inadequate to meet social needs. But complex issues will confront us; by the year 2000, said Mr. Johnson, "the relationship between material advantage and human values" may well be man's most vexing issue.

The problem will be compounded by the increasing cost and complexity of the technology needed in the 21st century, said Professor David C. White, Director of the M.I.T. Energy Laboratory. Risk will be larger, planning more important, the need for complete understanding of processes and their implications greater than ever before.

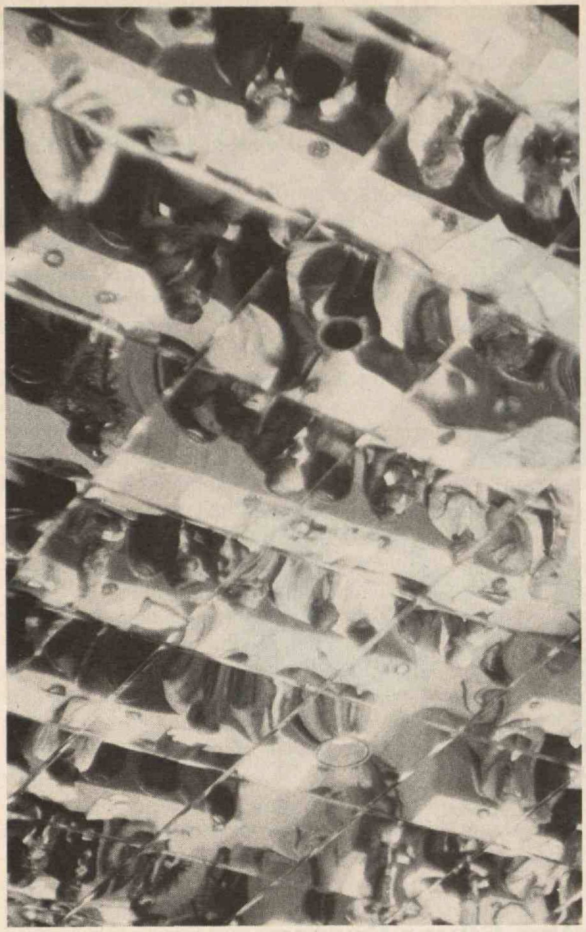
Indeed, said Professor White, dealing with risk may be the most difficult challenge — and that will be especially true if we determine to maintain, as all other speakers proposed, the free market system as a primary source of evaluations for decision making.

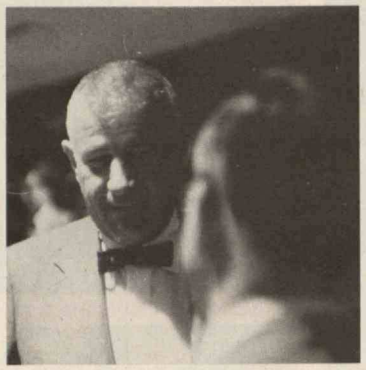
Other speakers included Samuel A. Goldblith, '40, Underwood-Prescott Professor of Food Sciences; J. Herbert Hollomon, '40, Professor of Engineering who is Director of the Center for Policy Alternatives; David H. Marks, Associate Professor of Civil Engineering; Robert M. Solow, Professor of Economics; and Lance J. Taylor, Professor of Nutritional Economics.

The day was organized by a committee of the M.I.T. Club of Northern California, of which George M. Keller, Jr., '48, was General Chairman. Paul M. Cook, '47, presided as Conference Chairman. ☐

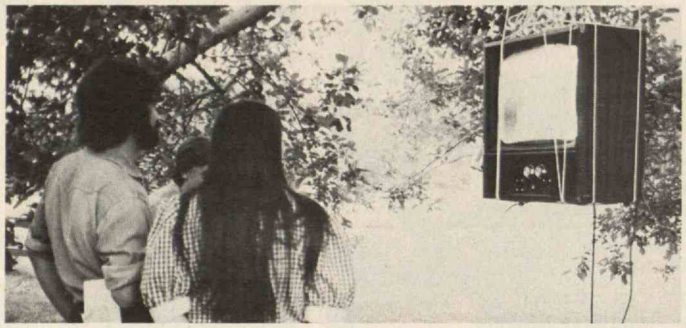


The title was simply "A Natural Resources Conference," but the mirrored ceiling (top, opposite) of the Hyatt Regency San Francisco reflected a ballroom filled to capacity to hear what proved to be a single message: traditional market forces have governed our supplies of natural resources in the past, and – despite scarcity and dislocations – they will do so in the future, said six members of the M.I.T. faculty. Above (left) is Professor David H. Marks; on the opposite page are Paul M. Cook, '47, General Chairman of the Conference; George P. Shultz, Ph.D. '49, keynote luncheon speaker (bottom, left); and J. Herbert Hollomon, '40, Director of the Center for Policy Alternatives (bottom, center).





A glimpse at one program of the U.F.S.C. – the Summer Institute for Film, Video and Photography. Richard Leacock, Professor of Film at M.I.T., and Ed Emshwiller, noted video artist, confer (far left); while students devise unusual ways to show and create video.



University Film Study Center: Pulling Down the Silver Screen

The great film figures of the past — Chaplin, Renoir, Hitchcock, Griffith — are experiencing a revival. And the film medium has gained an historical presence, spurred by departments for film studies in universities across the country. But the outlet is rare for the contemporary film artist, the harbinger of the future, whose work is unconfirmed by history or the box offices of commercial theatres.

The University Film Study Center has a foot in both worlds: it cultivates the study of film classics and the vanguard of the independent film artist. Founded in 1968 and housed on the M.I.T. campus since 1973, it is one of the best examples of the new genre of organization which promotes serious interest in film as an art form worthy of in-depth study. Among its services for 12 New England universities (including M.I.T.) which are U.F.S.C. members:

— A library of over 500 films, including the best in American and European cinema.

— Symposia at M.I.T. and elsewhere on subjects such as "Surrealism and French Documentary Film" and "The Future of Special Effects and Animation."

— Informal advice and formal conferences on curriculum design and resources for those embarking on university film programs.

— Center Screen, an alternative for Bostonians to the films shown in commercial theatres.

— The Summer Institute, an intensive three-week program in photography, video, filmmaking and film history.

The Film Underground Becomes Public

The idea behind Center Screen is to give the general public access to experimental and independently made films, which are rarely shown in movie theatres. To correct this, Center Screen's film programs have made available animated children's films, documentaries, a visiting filmmakers series, and most recently a program called "Sexual Metaphors" with films by avant garde artists such as Andy Warhol and Kenneth Anger.

"Sexual Metaphors" generated publicity for Center Screen in an off-handed manner when an article in the Boston *Herald-American* questioned: should Massachusetts taxpayers foot the bill for "sex-explicit" films? (Center Screen is partially funded by the Massachusetts Council on the Arts.) But the director of the Council, Ms. Louise F. Tate, was not disconcerted by the query. Her response was an affirmation: Center Screen "is one of the few organizations in this state promoting an interest in film through a highly successful film series including a wide range of artistically important films," Ms. Tate told the *Herald-American.*

Demystifying Film Techniques

The Summer Institute is an opportunity for students with all ranges of experience to understand the techniques of film and video, says Peter Feinstein, Director of the U.F.S.C. The point is not to produce film technicians. "We don't expect to give our students jobs," explains Mr. Feinstein. "It's not a vocational center. We approach the teaching of film like teaching English or any other art form. If you're an English major, you don't necessarily become a writer."

It is this attitude that suggests the preference of the U.F.S.C. for the independent artist to whom film is a medium for personal expression. Hence the U.F.S.C.'s choice of local independent film artists to produce a series of short films for the Massachusetts Council on the Arts. The goal was to educate the public to the work of artists throughout the state; one film captures the spectacular opening night of Sara Caldwell and the Boston Opera Company's production of "Benvenuto Cellini," another shows David Phillips' peculiar art of latex rubber peelings.

A familiarity with the process of filmmaking is important for children who are growing up in a world pervaded by its influence. "America Through the Eyes of its Children," produced for a children's show on Channel 2, Boston, is a lesson in animation by a group of twelve-year-olds. Before showing their own finished films, the children explain how they solved problems of movement and created images and sound.

"The reason for U.F.S.C.," says Mr. Feinstein, "is to provide support for the teaching of film and video as art forms and to draw the general public's attention to film and video as artistic mediums." — *S.F.*

Conventional Farming Can Feed World

The media blitz of horror stories of starvation in Africa is over, but the memories remained as several hundred food scientists gathered at M.I.T. in September for the 13th Underwood-Prescott Award ceremony and symposium.

But from three noted experts on world food problems they heard a message of optimism and challenge:

The world population *can* be fed properly with *conventional* agriculture, but it will take intelligent management to do it.

If advancing agricultural technology could be applied efficiently to all agrarian societies, said 1975 Underwood-Prescott Award recipient J. George Harrar, "world food production could at least be doubled."

"With sound international planning and agreements it would then be possible to stabilize distribution systems and to gradually reduce, if not eliminate, the sporadic famine or near-famine situations which prevail in many areas."

Dr. Harrar, President Emeritus and Life Fellow of the Rockefeller Foundation, was named Underwood-Prescott Award recipient "in recognition of his pre-eminence in public service to humanity in increasing and improving the world food supply."

If we fail to feed our population adequately, said Dr. Harrar, it will be because of our failure to deal with the population explosion; to lessen the social and economic conflict among nations striving for bigger pieces of the world pie; and the failure to ensure stable, realistic governments.

Dr. Harrar advocated a vigorous research program to continue developing methods to increase food production from both plants and animals, including:

— Manipulation of chromosomes and genes to yield new plants and animals

— Developing food crops that can fix their own nitrogen, reducing the need for fertilizers

— Learning better when, where, and how to apply fertilizers for maximum effect

— Creating safer methods of attacking pests

— Formulating new strategies for irrigating plants

— Learning new ways to return worn out soils to fertility.

— Developing nontraditional sources of food.

Nevin S. Scrimshaw, Professor of Nutrition at M.I.T., in his symposium address listed some of the unconventional food sources that could supplement conventional agriculture to feed humans or animals. His review of nontraditional food sources included many ways to better utilize food wastes, such as whey protein from dairy processes, infertile and broken eggs, meat and poultry wastes, and trash fish. He also emphasized the benefits of totally new protein sources — squid and Antarctic krill; single cell protein grown on waste petroleum or wood pulp; algae grown in shallow ponds; or leaf protein concentrates from leafy crops and wastes. Although still a remote possibility, synthetic foods built from elementary molecules might also fulfill some human needs.

But regardless of the source, any new food will have to overcome formidable barriers of economics, governmental regulation, and public acceptance, all of which make difficult any prediction of new food success.

Outlining the history and politics of some past world food programs, the Lord Ritchie-Calder, British interpreter of science, said, "What we have to examine is the nature of the hard work which is needed for a man-made miracle. We have to consider it as rationally as we can in a situation fraught with human catastrophe."

To those who advance the lifeboat ethic of deciding who should be fed: "Before we sit down at the console of the Doomsday Machine and decide which button to press, which races are expendable, which are ecologically unworthy and how many hundreds of millions and where are to be abandoned to starvation, let us face the facts, not as determinants, but as challenges to our imagination, our ingenuity, our managerial competence and our humanity."

The cautious confidence in man and his technology by Harrar, Scrimshaw and Ritchie-Calder was perhaps the most fitting tribute to William Lynn Underwood and Dr. Samuel Cate Prescott of M.I.T., who revolutionized food preservation in the 1890s by establishing scientific time and temperature guides for safely canning foods. — *D.M.*

Operations Up, But a $4.6 Million Shortage in 1974-75 Revenues

M.I.T.'s total operations in 1974-75 were $237,149,000, up from $224,352,000 in 1973-74. That's an increase of 6 per cent — less than the amount of inflation during the same period but more than almost any of the components of Institute income which could be used to meet expenses.

The result was that, despite intensive efforts to control costs throughout the Institute, unrestricted resources of $4,596,000 were required to meet operating expenses in 1974-75, Stuart H. Cowen, Vice President for Financial Operations, and Joseph J. Snyder, '44, Treasurer of the Corporation, told members of the M.I.T. Corporation in their annual financial report this fall. Of that total, $4,116,000 came from general unrestricted resources, only $480,000 from the Research Reserve.

Those figures compare with $5,309,000 of unrestricted resources required in 1973-74, of which $2,781,000 was obtained from the Research Reserve and only $2,528,000 from general unrestricted resources.

Balancing Expenses with Revenues

Only one item in the schedule of revenues and funds available to meet operating expenses grew at a rate faster than the total of operating expenses in 1974-75, said Mr. Cowen and Mr. Snyder. Departmental and interdepartmental research revenues were up 10 per cent; but this change barely matched the growth in the direct costs of departmental and interdepartmental sponsored research, up from $59 million in 1973-74 to $65 million in 1974-75.

Total gifts in 1974-75 — including those to the record-breaking M.I.T. Alumni Fund — were $20,282,000, compared with $21,406,000 in the previous year.

While the market value of M.I.T.'s investment portfolio was up $14.3 million in 1974-75 (due, say Mr. Cowen and Mr. Snyder, to the higher market value of both common stocks and fixed-income securities), investment income received in 1974-75 was down: $18,761,000 compared with $19,399,000 in 1973-74. The portfolio's market value has not yet returned to its record high value of nearly $441 million as of June 30, 1973.

Tuition and tuition-related income was $30 million in 1974-75, compared with $27 million the previous year.

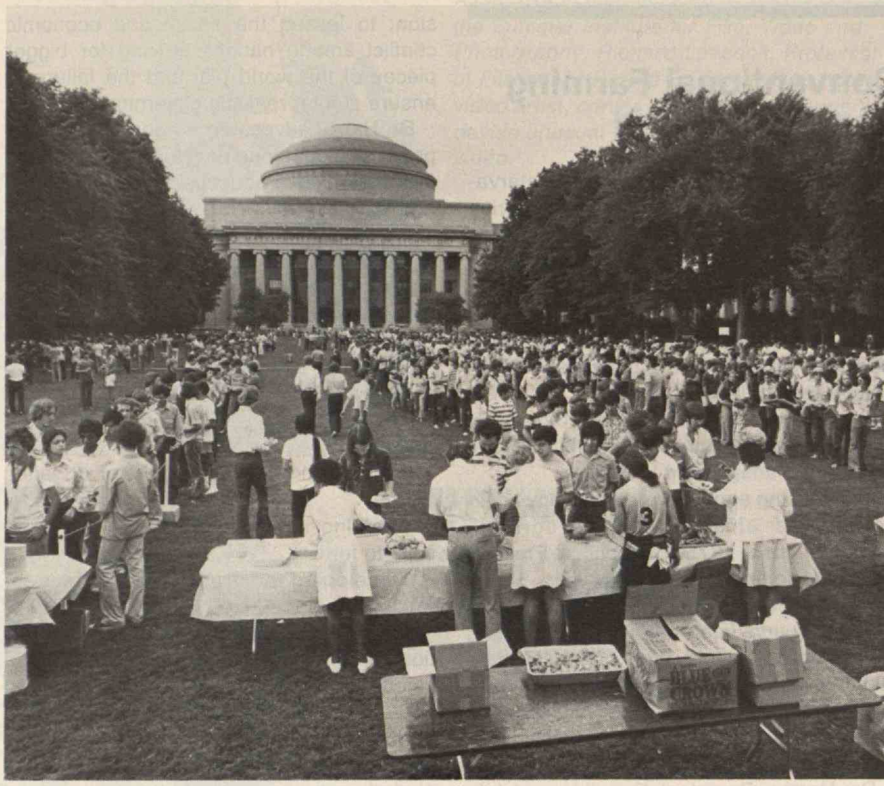
Endowment: Modest Growth

Gifts and bequests for professorships, fellowships, scholarships, and research support brought about a $3.9 million increase in M.I.T.'s endowment funds in 1974-75. The fund total at the end of the year stood at $344,907,000, of which $239,248,000 represented endowment.

The increase, wrote Mr. Cowen and Mr. Snyder, "adds to the strength and capability of the Institute to meet its responsibilities in education and research over the long term."

Meanwhile, major additions brought the book value of the Institute's educational plant to $197,513,000 on June 30, 1975 — up $7.5 million during the year. The increase represented chiefly the cost of the Seeley G. Mudd Building and of the modernization of the Ashdown House. ☐

Students



The first meeting of freshmen and Institute occurred on August 29 in the Great Court — a picnic for the Class of 1979 and its advisers, including President Jerome B. Wiesner, above. The balloon was engaged by Zeta Beta Tau to carry its prospective pledges from the picnic to its Brookline house, but a brisk evening breeze forced reliance on more conventional transport. (Photos: Calvin Campbell and Mark H. James, '78, and Thomas R. Vidic, '76, from The Tech)

The Recession Freshman: High Marks, Low Bank Balances

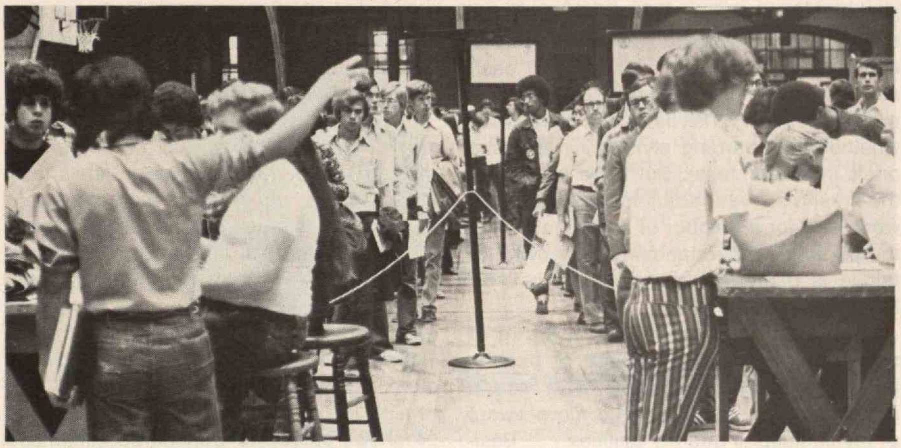
This year's freshmen class of 1,169 students is M.I.T.'s largest. In the midst of a recession, they have come to one of the country's most expensive universities; to make that possible, 679 of them have received financial aid from M.I.T. and other outside sources.

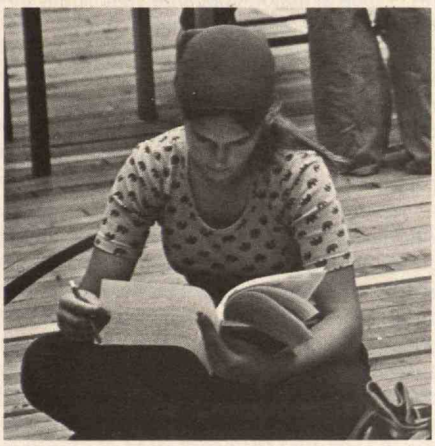
M.I.T.'s new students begin their adventure here with enthusiasm. The statistics that describe them are easy to list: an extraordinary record of academic performance — averaging in the 99th percentile of College Entrance Examination Board mathematics achievement, the 91st percentile in verbal and English achievement; 91 per cent were in the top 10 per cent of their high school classes; 176 are women; 104 are members of minority groups.

It is more difficult to decipher their collective influence and individual characters. "New students seem more conservative, more traditional, less risk-taking, more concerned about their personal future and economic future," says Peter Büttner, '61, Associate Dean for Student Affairs, of the trend in the last few years. He thinks, too, that his advisees this year seem to be the most mature group he has ever seen — and some other advisers have said the same.

The freshmen have some unusual achievements: one is a horseman with several international prizes in jumping; one spent the summer on a Japanese oil tanker with only one other English-speaking crew member; one was a Country and Western disc jockey and station operator for an 80 kilowatt station; one rode his bicycle here from New York City.

Some say that today the investment in a college education is not a clear-cut one — many college graduates have found it difficult to find employment. But "in spite of the continuing recession, the Institute's graduates found their talents generally in demand," write President Jerome B. Wiesner and Chancellor Paul E. Gray, '54, in their 1974-75 report to the M.I.T. Corporation. □





Chancellor Paul E. Gray, '54, says a "dominant characteristic" of M.I.T. is "hyperactivity." That's true even on Registration Day, at the beginning of each term; but students complain that standing in lines to let computers plan schedules is pointless and frustrating. "Sure it causes problems," Ronald P. Smith, Associate Registrar, told The Tech *this fall; "but it gets a lot of things done that would be difficult to do otherwise." (Photos: David A. Schaller, '78, and Leroy A. Lindquist, '79, from* The Tech*)*

And Now for Something Completely Different: E.S.G. and Concourse

Imagine you are a freshman just arriving at M.I.T. The environment is totally new. You have concerns about the future, doubts about the relationship of required courses to future goals, questions about self-worth and capacities, and anxiety that many highly desirable options may be closed forever each time a choice is made. And a regimen of formal lectures, classes, assigned homework, and exams turns you off.

For your first year, M.I.T. offers you two alternative methods of study: Experimental Study Group and Concourse.

E.S.G. is largely what you make it (like most other things at M.I.T.) You may study a number of topics at the same time, or concentrate on just one — whatever suits you best. Your personal approach to physics may differ from your personal approach to sociology. You will have complete freedom in choosing the way you learn, and you may decide the way you wish to be evaluated by consulting with a staff member. Participation and interaction by students and staff on a personal as well as academic level is the basis of E.S.G.

Of course students must be evaluated to assure that their work has been done, and it's also important that E.S.G. freshmen develop a capability for self-judgment. (The staff's judgment of students can be an important help to students who are learning to judge themselves.) You can show your instructor you have learned physics, for instance, by doing an exam with or without books, by reading a scientific paper and writing a commentary on it to show you understand it, by giving a lecture, by taking an oral exam, or in other ways you may suggest. Credit in an Institute subject is obtained by convincing an appropriate E.S.G. faculty member that you know approximately what you would have known by completing that subject in the regular curriculum. In humanities, you can obtain credit by doing an appropriate amount of work in a non-science field, whether or not that field corresponds to subjects offered in the regular humanities program.

Benefits Differ for Each Freshman

Listen to one student: "The most important thing E.S.G. has done for me is to allow me to discover what my immediate goals truly are and to see how these goals may point toward longer-range goals. Being essentially free to do as I pleased (at least, that is the way I have felt), I have been forced, by myself, to determine why I am participating in activities in which I find myself. In searching for those reasons, I have acquired a greater understanding and, therefore, a greater appreciation of those activities."

E.S.G. does not provide a four-year academic program; by the second half of the sophomore year, its members must pursue formal upperclass course work. But this does not mean leaving the E.S.G. community; many juniors and seniors spend time there tutoring, studying, eating, listening to music or talking.

What was their reaction upon returning to the regular curriculum? Some said it was easy because someone else makes up your mind for you; some feel restricted by narrowly defined and required subject matter, testing, and homework. But few have had difficulty doing the work required in regular classes.

"The most important thing I've learned this term — and, unfortunately, it took almost the entire term — was that it *is* possible to organize my time. I'm just beginning to be able to do the things I have to do without getting bogged down with work which is not helping me learn anything. This is what's called 'selective neglect' around M.I.T., it's a new idea for me — I guess I worked that way some in high school but I never needed it on a continuous basis."

Nothing is Guaranteed

There are rewards — and risks — in the E.S.G. program. It is not guaranteed that E.S.G. students will learn as much formal subject matter as their colleagues in regular subjects with assigned homework, recitation classes, and exams. It is up to each student — perhaps he (she) will learn more; perhaps less. The risk lies in the question of whether this learning style will really suit one's individual taste. But there is more to the freshman year than formal academic work, and for a number of E.S.G. students, the personal understanding and growth attained is a greatly valued aspect of their freshman year.

"I have become much less awkward at social interaction, more aware of people, better at communicating with them. Academically, I have become more aware of my limitations and my abilities . . . Basically, I feel I've grown more stable, more experienced by definition, more realistic, and somehow, intangibly, more mature. I also still have a long way to go."

Concourse — Interdisciplinary Topics Unified by a General Theme

Concourse is a different, more structured approach to individual learning, an exploration revolving around a unifying interdisciplinary theme — this year, "Mind, Machine, and Meaning." Subtopics include computers and computation, "artificial intelligence," neurophysiology, the mind-body problem, perception, and communication theory. "There isn't a single thing you can touch which all sciences aren't tied into together," Professor Jerome Lettvin told freshmen interested in the Concourse program.

Teaching styles vary with subject matter in this small community of students and faculty — lecture, seminar, lab, tutorial, debate. Team teaching is frequently used. Assignments are generated by quizzes, problem sets, papers, and exams. Each assignment carries a certain number of points for Institute requirements; each student and his advisor have a weekly record of the student's progress in terms of points. Regularly scheduled sessions to explore selected interdisciplinary topics extensively involve all Concourse students and a sizeable group of faculty. Class size varies with the daily format from a maximum of 50 students, to 10 or 15 in seminar and problem-solving sessions, to one-on-one tutorials.

"The 50 students in the Concourse are not shackled hand and foot to their 49 colleagues," said Professor Lettvin, "they can take courses outside. Those of us who teach in Concourse have found a strong rapport. It has spoiled us and the students. Life during that first year, you will find, is a remarkable life." Students agree.

— Brent Cochran, '78: "The biggest thing for me in the Concourse program was getting to know the professors — on a first name basis. And we had *input* into what we learned. We would bring it up in class if we didn't like a topic or method of teaching; professors would talk about how they felt about the students and we would talk about how we felt about them. I was let down this year in the regular program — it seemed so futile to be in a large lecture hall with 600 students. For example, one of my classes this year is very poorly taught — and there is no input to change it. If this happened in Concourse, students could suggest changes.

"I think the grading system in Concourse took some pressures off us. In the general Institute, more value is given to finals than in Concourse, where it was more important to master each problem set. This year, in my regular courses, the final exam is worth 40 per cent of my grade in three courses. That's ridiculous! Anyone can blow one exam — and that's half your grade."

— Brian Pinette, '78: "I think I learned a lot more in Concourse than I would have in a regular Institute course — and exposure to programs unique to Concourse influenced my choice of major. I became specifically interested in Artificial Intelligence . . . One disadvantage is that this year, in some ways I'm like a freshman — I'm not adjusted to the regular Institute program; I don't know any of my professors. (But there are always teaching assistants, so it's not all that cold.)"

— Jennifer Hall, '78: "I liked the idea of an interdisciplinary program with a smaller group (sitting in a lecture with 600 people would have terrified me.) This year I find the program is no harder academically. It has been less personal — the professors don't seem to really care (in Concourse they sort of watch out for you.) . . . There is a larger ratio of women in Concourse (perhaps about one-third last year.) Many of the women were interested in liberal arts, and Concourse stresses humanities more than the Institute's regular program."

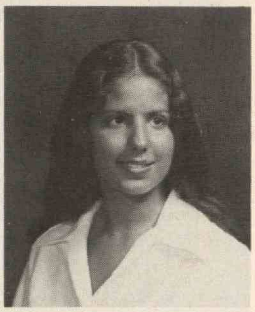
— Richard Ware, '78: "Concourse gave me an opportunity to know 50 people very well; we could help each other. And we learned not to fear professors; to ask for their help. This gave me more confidence; this year I

will not be afraid to talk to professors and teaching assistants . . . There is the rumor that Concourse is easier; that we didn't have to work. That isn't true. We *did* work, but in a better atmosphere."

— Rob Milne, '78: "We thought about the question 'how can you have a spiritual mind in a physical brain?' When I first looked at it, it seemed simple — then three-fourths of the way through the term it looked impossible. But we studied physics, calculus, and computers, and by the second term it was all tying together. I think in a year we covered the topic thoroughly. . . . Every now and then we would get a few Ph.Ds in spontaneous debate. It was absolutely amazing and fascinating to listen — it gave me an idea of things to come." — *M.L.*

The Red Queen Was Right

A coed recalls the mutual exploration of freshmen and Institute during R/O Week.



Technology Review *asked Margot V. Tsakonis, '79, of Fort Devens, Mass., to write about her impressions of R/O Week for this month's issue. In high school, Margot edited a literary magazine that she started, was Assistant Editor of the yearbook, and sang in school musicals, a madrigal group and the glee club.*

Residence/Orientation Week was a kind of art by immersion, a sudden and total violation of preconceptions that freshmen had nurtured throughout the summer. Innumerable letters from fraternities and that revered volume, the "Freshman Handbook," had occupied many summer hours. But no amount of paper could convey the essence of the M.I.T. experience; despite the rain of information, M.I.T. remained an unknown quantity.

That very unknowing, that haze of obscurity, rendered the freshmen and the Institute alike mutually needful of exploration during Residence/Orientation Week. Each new encounter — whether a fraternity party, a women's get-together, or a casual conversation in the coffee-house — was an opportunity to eliminate false stereotypes, to create anew my personal identity as a student, and to establish a foundation for my role at M.I.T. My predominant recollection of R/O Week is the impression that, like a sculptor, I had before me a mound of dampened clay awaiting only the touch of my hands to spark it to life.

The returning students involved in R/O were genuinely anxious to ensure that our sudden immersion was enveloping but not overwhelming. Advisers, associate advisers, and tutors, as well as committees ad infinitum, actively aided in the initiation. But I found the richest sources were individual students, both my new classmates and upperclassmen.

Freshmen were the unsuspecting objects of unparalleled interest, instantaneously a focus of attention wherever we went. Of course there were awkward moments (being the only coed at a party full of Wellesley women) and a few incredulous stares as cynical upperclassmen insisted that I *couldn't* be from M.I.T.

R/O Week used to be called "Rush Week," and that is an especially appropriate name for this frenetic euphoria. In recollecting it, I realize that I was merely part of a grand annual rite, a ceremonial through which thousands had passed before me. Yet I hope that the warmth, the lightheartedness, even the interludes of that peculiar brand of insanity which is credited to college students, do not fade with the season. In that respect, I think the "rush" endures. For as Lewis Carroll's Red Queen explains, "Now, *here* you see, it takes all the running you can do to keep in the same place." — *Margot V. Tsakonas, '79*

Aid For Computer Freaks

Michael Haney, '77, wanted to learn some neat tricks to get him through a computer course when he arrived at M.I.T. as a freshman, so he requested funds from the Student Information Processing Board to learn a computer language. "It didn't work — I learned nothing useful about programming," he said.

But the Board became one big happy family for him, and now, as Chairman, he explains the S.I.P.B. to others.

"The mechanism of membership in S.I.P.B. is almost exclusively by osmosis," he said. "You just hang around, go to at least four meetings, and on the fifth you will be nominated for membership. As a member, it is essential to help users with problems. But that doesn't imply that new members must have vast knowledge of computers; they tend to have a strong interest, and learn quickly. If a user asks a question of a new board member who does not know the answer, he can find a more experienced member who does, and listen to the explanation." More often then not, new members are incoming freshmen.

Essentially, the S.I.P.B. is the custodian of a $100,000 budget provided by M.I.T. so that undergraduates can use computers for projects of their choosing. "Lots of people come in and say nothing more than they want to learn about the system — and we fund them. They are more than welcome to ask for more; and they will get it as long as they demonstrate that their work has progressed in some manner and is heading in some definite direction," Mr. Haney said. Grants range from $40 to about $700. To allot funds, the board tries to determine how large a job is — and the abilities of the programmer. S.I.P.B. reviews all requests at weekly Monday night meetings and votes on who should be funded. All users with large requests are invited to present their cases at these meetings. Small requests, within the limits of Board policy, are approved on the spot at any Board member's discretion.

"We also provide free services," said Mr. Haney. "The Educational Calculator System, funded by S.I.P.B., allows any person in the Institute to dial into the computer to use it as a calculator." The user need have no contact with S.I.P.B. at all.

Students have used S.I.P.B. funds for many kinds of projects. One student wanted to compute the best route from one point to another on the M.I.T. campus; he set up a program so that the most direct path between two designated points could be modified by specifying a scenic route, or an appropriate route for a person on crutches, for example. Another student explored genetic codes seeking cell patterns; another searched for a fast, easy way to determine malnutrition by comparing a subject's weight to body measurements.

"Even if the project doesn't get completed," said Mr. Haney, "if the student has learned something in the process, then we've won."

The funded S.I.P.B. user has a choice of methods: Multics (used at a terminal from a Honeywell 6180), Batch 370 (I.B.M. 370-168) and TSO (similar to Multics, but connected to the I.B.M. 370.)

Multics is extremely user-oriented; there are few things a user can do to mess it up; it is easy to write a program and hard to destroy it; it is so flexible that it handles simple or intricate problems. But too many users competing against all the others running their programs slows the machine. (Some call Multics the world's slowest computer although this is not true.) "When the total number of users reaches anywhere between 60 and 80, the user is subject to preemption — he or she may be pushed out."

A Batch user types a deck of cards, hands them to the operator and waits for them to come back. He can give his job priorities (the price increases as the priority goes up.)

The price of a job is computed by considering various processes: the amount of time

the central processor spends on the program, the use of magnetic tapes and disc space (because these are limited facilities, they must be paid for). Additional charges are made for "memory units" which approximate the cost of using the machine. The program generating a number for these charges measures the unmeasurable: the tasks performed by the computer as it processes the program.

"We are not plagued by overspending," Mr. Haney explained. "If people inadvertently spend $20 or $50, we just tell them to be more careful. When a regular user is careless, he knows we will respond by not giving him any more time." — *M.L.*

Low-Cost Solution to the Saturday-Night Problem

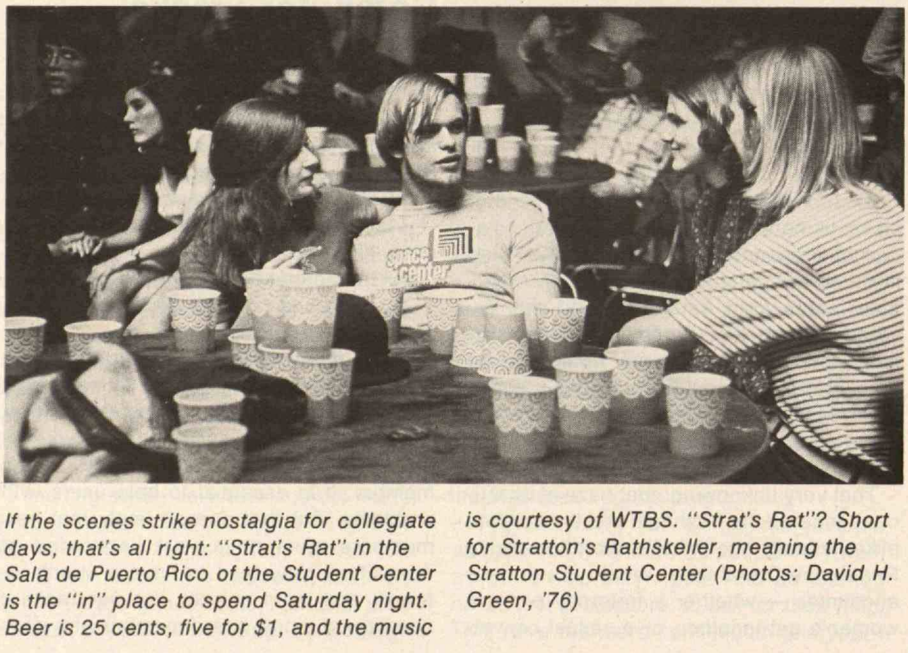
What to do for a simple, sociable Saturday night in Cambridge?

The answer for hundreds of students is "Strat's Rat," an anti-inflation hangout where you eat, drink, and party without spending much.

The name is presumably a shortening of Stratton's Rathskeller, though the terms are at best vaguely related to the scene they describe. The connection with Julius Adams Stratton, '23, is through the building which bears his name; and to imagine a rathskeller inside the spacious Sala de Puerto Rico is a demanding exercise.

No matter. Beer at 16 ounces for 25 cents — or five for $1 — and ear-splitting music from the record collection of WTBS, M.I.T.'s radio station, combined to make Strat's Rat a campus institution. Up to 450 people spent Saturday night (8:30 p.m. to 1 a.m.) there last spring, and at least ten kegs of beer — plus pretzels and potato chips — were typically consumed.

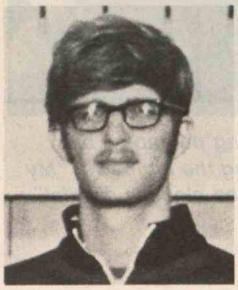
Katrina M. Wooton, '77, who heads the Student Center Committee, says the beer paid for itself — and a little more. But the cups, "munchies," and services of a member of the Campus Patrol put the budget a bit into the red; to save the cost of overtime labor, the Committee members cleaned up the Sala themselves. □



If the scenes strike nostalgia for collegiate days, that's all right: "Strat's Rat" in the Sala de Puerto Rico of the Student Center is the "in" place to spend Saturday night. Beer is 25 cents, five for $1, and the music is courtesy of WTBS. "Strat's Rat"? Short for Stratton's Rathskeller, meaning the Stratton Student Center (Photos: David H. Green, '76)

The Sports Desk
David A. Dobos, '77

N.C.A.A. and the Participation Principle



Last August the National Collegiate Athletic Association adopted legislation limiting the size of both home and travel squads for 18 varsity sports. For example, home football squads may dress only 60 players and the visiting team is limited to but 48. Basketball personnel have been decreased to 13 at home and 10 on the road.

Much of the justification for the cutbacks is economic. With travel expenses at an all-time high, it is simply too costly for universities to send large squads cross-country for athletic contests.

However, financial issues are only part of the motives behind the new measure. Large Division I schools, the chief proponents of the reduction, feared encroachment by highly-competitive, recruiting rivals. They wanted a common denominator among all universities for at least one facet of their respective athletic programs, suggesting that a prospective student should not have to choose a college because of the apparent wealth of its athletic department. The legislation was designed to restore some of his decision-making flexibility.

How are the varsity team cutbacks affecting M.I.T.?

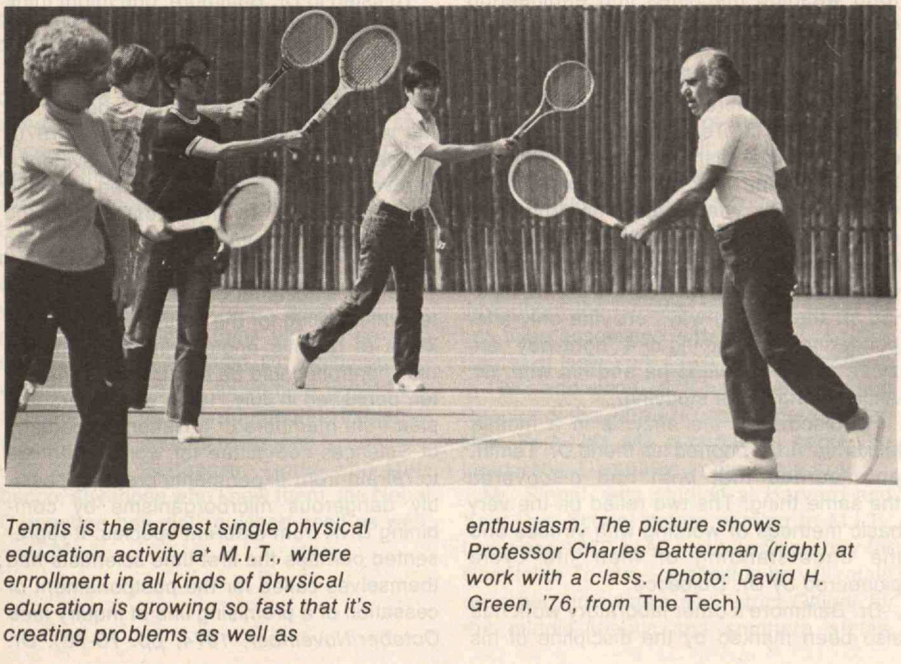
During the past fall season a phenomenal 95 students drew equipment for intercollegiate soccer, and 25 of them earned varsity status. But N.C.A.A.'s new limits on soccer are 23 for home games and 18 for away. In M.I.T.'s case, the cutbacks meant that not only did some varsity players miss actual competition, but as many as 50 junior-varsity players were excluded from action (the quotas affect junior-varsity squads as well).

A record 33 men turned out for the cross-country team. At most, though, 22 (11 varsity and 11 junior-varsity) could run in home meets and the traveling squad was restricted to 18 (nine of each). The effect, says Coach Peter Close, is that the athlete who cannot quite make a team loses all incentive to stay out for that squad; because of the limitations, he knows he will not compete.

The varsity team reductions are inconsistent with M.I.T.'s philosophy of maximum student participation in athletics. As John Underwood wrote in *Sports Illustrated* last May, "For M.I.T. it's not how you play the game, but that you have a ball playing it." The economic reasons for smaller squads are not appropriate here: it costs nothing to dress extra players for home contests, and a half-empty bus is just as expensive as a full one for away trips. Also, M.I.T. does not actively recruit high school athletes. Students choose M.I.T. primarily on its academic reputation, not because of its sports program.

"The real issue at hand," says M.I.T. Athletic Director Ross H. Smith, "is that of institutional autonomy." Professor Smith feels that each university should determine its own policy consistent with its particular budget constraints; M.I.T. should not have to abide by measures that do not apply to its situation. Therefore, he and athletic directors from other Division III (the academic, non-recruiting, small colleges) institutions will introduce a proposal to eliminate all national legislation on limitations for Division III intercollegiate squads at the N.C.A.A. convention in January, 1976. Should this measure fail, the N.C.A.A. Executive Council has already proposed to amend the existing restrictions to eliminate quotas on home teams and to increase travel squads.

If the member universities of the N.C.A.A. will agree to institutional autonomy for Division III colleges, concerning not only squad limitations but also proposed legislation dealing with scheduling practices and varsity awards, then the M.I.T. philosophy of athletic participation will be preserved. □



Tennis is the largest single physical education activity a' M.I.T., where enrollment in all kinds of physical education is growing so fast that it's creating problems as well as enthusiasm. The picture shows Professor Charles Batterman (right) at work with a class. (Photo: David H. Green, '76, from The Tech*)*

Keeping in Shape

Is it *Sports Illustrated*'s fault?

No one seems to know. But this fall, just as the N.C.A.A.'s limitations on varsity teams went into effect *(see left)* the M.I.T. Athletic Department found itself with an embarrassment of numbers.

Almost 100 students turned out for soccer practice in the first two weeks of the term; cross-country drew almost 50, and tennis, golf, and baseball had record turn-outs, too.

Meanwhile, physical education classes seemed to be going from something that is required to something everyone wants to take.

M.I.T. graduation requirements include eight "points" of physical education credit; each one-term class is worth two "points." But that's not the problem. "There has been a very steady increase in the number of people taking physical education for no credit," Professor Edward A. Crocker, Director of Physical Education, told Gerald Radack, '77, of *The Tech* this fall, and "the non-credit group is getting to be more and more of a problem."

Last year there were 2,653 non-credit registrations for physical education — 39 per cent of the total. That's growth at the rate of about 500 a year. Tennis is now the largest single activity, with dance a close second. Sailing, rifle and pistol, and skating are other popular choices.

The problem, of course, is facilities. Rifle and pistol are limited by the size of the ranges, skating by the length of the season (mid-November to March) and the size of the rink, sailing by the number of dinghies. Hockey can only be taught during the Independent Activities Period, when the rink is not needed for skating classes.

People

Nobel Laureate Dr. David Baltimore, looking perhaps a bit bewildered at a press conference following the big news: "My God, I've never seen so many Nikons in one place in my life!"

David Baltimore, Nobel Laureate: About Time

And so, though the paper in Nature *was terse,*
(The one in which David of B
Presented his work on transcriptase reverse)
And not unexpected, you see,
A highblown committee of Swedes then came down
And said, "You have searched Nobel-ly."
They set him up on the faculty
Of this college by the sea.
– from "David of B" by Robert Bender

At 7:30 in the morning on October 16, David Baltimore, Professor of Microbiology at M.I.T., was awakened by a phone call from his wife, who was attending a scientific meeting in Copenhagen. The news: he had been named one of the three recipients of the 1975 Nobel Prize in Medicine and Physiology, for "discoveries concerning the interaction between tumor viruses and the genetic material of the cell." The other two recipients were his long-time colleagues Howard Temin of the University of Wisconsin and Renato Dulbecco of the Imperial Cancer Fund, London, England.

Dr. Baltimore was "shocked, elated, ecstatic" as he said later at a news conference. Certainly, the M.I.T. community was elated and ecstatic. But it was far from shocked. Dr. Baltimore's name had invariably popped up in conversation every year during Nobel time since 1970 when he and Dr. Temin had independently discovered the enzyme reverse transcriptase, which, very simply, revolutionized thinking about the relationship between genetic material and the cell.

At a party for Dr. Baltimore a poem circulated — a verse of which is reproduced above. It was written, not in 1975, but in 1972, certainly only half in jest.

When asked for his comment on the prize, Dr. Jerome Wiesner, president of M.I.T., allowed that "The prize itself had already been discounted; we were elated when the work was actually done."

There was good reason for elation when Baltimore and Temin published their results independently in the June 27, 1970, issue of the journal *Nature.* They had grabbed the world of biology by the hair, twisted it around, and sent it scurrying down a whole new corridor of thought.

They had proved that an enzyme existed which could reverse the normal DNA-to-RNA flow of genetic information in a cell — transcribing DNA *from* an RNA blueprint; hence, the name "reverse transcriptase." Their finding explained for the first time how viruses possessing an RNA genetic core could insinuate their genetic information into the DNA genes of the cells they infected.

In 1970, the one-wayness of the DNA-to-RNA pathway was the "central dogma" of molecular biology, drummed into the heads of countless college students to be dutifully spewed forth on examinations. To contend anything different in those days was to assert that an assembly line could be reversed, and from the end-product would come its blueprint. This conjured visions of a backasswards world which could transform washing machines into engineering drawings, automobiles into drawing-board sketches.

Obviously the scientific world would not believe such a heresy without incontrovertible evidence; Dr. Temin had seen his theory of reverse flow dismissed, even ridiculed, because of the lack of evidence. He had worked for six years before he found evidence of the enzyme in the Rous sarcoma virus, which affects chickens. In contrast Dr. Baltimore had just entered the arena, looking for the "wrong-way" enzyme only after pondering the meaning of a "right-way" enzyme in another virus he and his wife, Dr. Alice Huang, were studying.

He discovered the enzyme in a mouse leukemia virus, phoned his friend Dr. Temin, and learned that both had discovered the same thing. The two relied on the very basic methods of working with viruses and the understanding of their life cycle pioneered by Dr. Dulbecco.

Dr. Baltimore's other laboratory work has also been marked by the discipline of his continuing research on reverse transcriptase. He is well known for his studies of the reproduction of polio and mengo viruses, and for his work on enzymes in the immune system. Dr. Baltimore and his colleagues announced in 1972, simultaneously with laboratories in New York and Bethesda, Maryland, synthesis of part of the gene for globin, the protein part of hemoglobin.

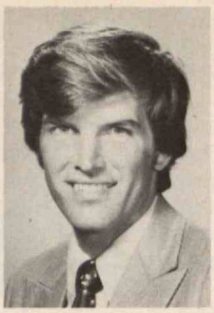
For Dr. Baltimore, the Nobel Prize is the latest in a great number of honors, especially extraordinary for one so young — he is 37. He is the American Cancer Society Professor of Microbiology in M.I.T.'s Department of Biology, which means that the Society provides the major support for Dr. Baltimore throughout his research career. He is also head of the tumor virology group at M.I.T.'s Cancer Research Center, housed in the candy-factory-turned-laboratory of the Seeley G. Mudd Building.

Among his other honors: membership in the National Academy of Sciences, the 1970 Gustav Stern Award in Virology, the 1974 U.S. Steel Foundation Award in Molecular Biology, and a co-recipient of the 17th annual Gairdner Foundation award for "contributions to the conquest of disease and the relief of human suffering."

To listen to Dr. Baltimore, one might think he was a one-dimensional man. He describes himself as "a spectator" when it comes to outside interests. But the well-liked Dr. Baltimore has been no spectator in the world outside his laboratory. In 1970, the day after he obtained the first evidence of reverse transcriptase, he closed down his laboratory for a day in protest against the Cambodian invasion. ("Oops, I mean *incursion*," he says.)

He was a cosigner of the now-famous letter which called for the deferment of certain kinds of genetic engineering experiments until controls could be established. The letter, published in July, 1974, was a personal plea from members of a National Academy of Sciences committee for world scientists to refrain from experiments creating possibly dangerous microorganisms by combining DNA from different species. It represented perhaps the first time scientists had themselves called for the postponement or cessation of a promising line of inquiry (*see October/November, 1974, pp. 75-76*). Dr.


R. H. Bliss


K. J. Kinsella


J. N. Phinney


A. H. Singal


S. P. Denker

Dr. Baltimore Joins M.I.T.'s Nobel Crowd

Dr. Baltimore's Nobel Prize brings to four the number of Nobel laureates on the M.I.T. faculty; the others are Alfred P. Sloan Professor of Biology and Chemistry Har Gobind Khorana (1968), Institute Professor and Head of the Cancer Research Center Salvador Luria (1969), and Institute Professor of Economics Paul Samuelson (1970).

Institute alumni are also well-represented among Nobel Laureates: William Shockley, '36, received the 1956 prize in physics; Richard P. Feynman, '39, the 1965 prize in physics; Robert B. Woodward, '36, the 1965 prize in chemistry; and Robert S. Mulliken, '17, the 1966 prize in chemistry.

Baltimore was also an organizer of the February, 1974 "Asilomar Conference" in California at which over 100 scientists gathered to begin work on controls for research involving genetic engineering.

Dr. Baltimore and Dr. Temin had knocked one dogma into a cocked hat, but they both adhered religiously to another rule of science in their comments upon winning the prize — the rule that a scientist be a dispassionate advocate of truth. Although they had both spent their professional lives trying to puzzle out the riddle of tumor viruses, both expressed doubts about the value of their work in curing cancer. Dr. Temin said outright that he didn't think viruses caused cancer in humans. Said Dr. Baltimore, "I would rather see the movement toward examination of the environmental, industrial and chemical causes of cancer."

In naming Baltimore, Temin and Dulbecco, say those who know them, the Nobel Committee has distinguished itself as well. — *D.M.*

Regional Support for Alumni and Campaign

M.I.T.'s strength in the field has been augmented during the fall by new appointments for five alumni:

Robert H. Bliss, '48, Kevin J. Kinsella, '67, James N. Phinney, and Arnold H. Singal, S.M. '63, have been named District Officers for the $225 million Leadership Campaign.

Stephen P. Denker, '60, formerly Senior Project Engineer at the Schlumberger-Doll Research Center in Ridgefield, Conn., will succeed Mr. Phinney as Regional Director of the M.I.T. Alumni Association for the New York, New Jersey, and Philadelphia areas.

Mr. Bliss, who will work with alumni in the midwest in support of the Leadership Campaign, was Planning Director for USM Corp. in Boston; he studied mechanical engineering and returned to the Institute as a Sloan Fellow for his Master's degree in the Sloan School of Management in 1958, and he has been active in alumni affairs since his undergraduate days.

Following graduation from M.I.T. in management, Mr. Kinsella studied international economics at Johns Hopkins University (M.A. 1969) and the University of Stockholm International Peace Institute (1970-71), and he was Deputy Director of the Latin American Teaching Fellowship Program at the Fletcher School of Law and Diplomacy of Tufts University; his assignment for the Leadership Campaign is the western United States.

Mr. Phinney is well known to alumni throughout the Greater New York area; he has been associated with the M.I.T. Alumni Center of New York since its establishment in 1963 and since 1972 has been Regional Director of the Alumni Fund for metropolitan New York. He will continue to serve the Leadership Campaign in the same area.

Mr. Singal, who studied at Harvard and Yale Law School before coming to M.I.T., has since 1972 been Institute Secretary for Charitable Trusts — a position he will retain on a part-time basis as District Officer for the middle-Atlantic and southern states. From 1963 to 1968 he was Vice President for Research, Planning, and Development at Federal Distillers, Inc., Cambridge.

Dr. Denker, who joins a regional organization of the Alumni Association supporting alumni efforts in behalf of the Alumni Fund, the Educational Council, and clubs, studied electrical engineering and solid-state physics at the Institute (S.B. and S.M. 1960, Ph.D. 1963); he was elected to both Tau Beta Pi and Sigma Xi, and he has been active in the Institute of Electrical and Electronics Engineers, the American Physical Society, and the Society of Petroleum Engineers of A.I.M.E.

Following his M.I.T. work, Dr. Denker was for four years Assistant Professor of Electrical Engineering at Columbia University, teaching courses in electronic circuits and materials; since then he has had industrial assignments in solid-state and electronics engineering. His home is in Stamford, Conn., and his office will be in the M.I.T. Alumni Center of New York, 50 East 41st St. □

Sargent Joins Joint Center to Ponder Politics and Planning

Is planning for regional development and environmental protection politically impossible in Massachusetts?

During his last term as Governor of the Commonwealth, Francis W. Sargent, '39, found that question recurring and troublesome. Now, just nine months after he left the State House, Mr. Sargent will ponder it from a different perspective. For he has become a Senior Lecturer in the M.I.T. School of Architecture and Planning and in Harvard's Graduate School of Design, and he will lead seminars for faculty and advanced graduate students in the Harvard-M.I.T. Joint Center for Urban Studies on public policy, land use, and the environment.

It was last June that Mr. Sargent told the M.I.T. Club of Boston that "we may have gone too far" in our zeal for environmental

S. H. Crandall

M. C. Flemings, Jr.

D. R. F. Harleman

protection. He recalled that "I fought like crazy to have environmental quality considered equally with economy and safety in planning highways," and finally that he ruled against highways and in favor of mass transportation within Greater Boston.

But now Mr. Sargent fears that "there are so many environmental restraints that we seriously jeopardize progress," he told the M.I.T. alumni group. "It's almost impossible to get anything done," he said, and he hopes that somehow the political process can be changed enough so that logical regional planning becomes more possible.

"Americans must learn that planning is *not* a dirty word," said Mr. Sargent. "Reckless, unplanned development in the name of economic recovery is not acceptable, nor is the unrealistic negativism of no-growth."

Mr. Sargent's assistant at the Joint Center will be Lewis Crampton, who was Commissioner of Community Affairs in the Sargent Administration and is now completing his doctorate in the Department of Urban Studies and Planning at M.I.T. □

Ford Professors

Ford Professorships, recognizing interdisciplinary contributions through research and teaching to newly emerging fields of engineering, have been assigned to three members of the M.I.T. faculty:

— **Stephen H. Crandall,** Ph.D. '46, Professor of Mechanical Engineering, is an expert on solid mechanics and especially on random vibrations, a field which he pioneered since its importance became clear in the development of jet and rocket engines. More recently Professor Crandall has turned to problems of noise transmission and earthquake protection in buildings.

— **Merton C. Flemings, Jr.,** '51, Associate Director of the Center for Materials Science and Engineering, has achieved recent distinction for work on metal casting in the context of modern industrial needs; he is the author of a highly regarded text on casting processes, and he has made significant contributions in other fields of physical metallurgy as well.

— **Donald R. F. Harleman,** Sc.D. '50, Professor of Civil Engineering, is Head of the Water Resources and Environmental Engineering Division of the Department and Director of the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics. His research and teaching cover such diverse fields as hydrodynamics, water quality, coastal engineering, and the modeling of complex water systems; he is known especially in the field of waste heat disposal, and Professor Harleman is given credit for encouraging M.I.T. students and faculty to broaden their interests in aquatic ecology, water chemistry, and environmental management. □

Howard Johnson as President of M.F.A.

Howard W. Johnson thinks art "plays a vital role . . . in the process of the education of everyone." For himself, he's been "motivated by an interest in the aesthetic" throughout his life.

Reason enough, then, for him to undertake the job of Boston's prestigious Museum of Fine Arts. Mr. Johnson, Chairman of the M.I.T. Corporation, has been the Institute's representative on its Board of Trustees since 1971; this fall, upon the resignation of John Coolidge, he was named President of the Board.

What will be his role in that office? asked Patrick McGilligan of the *Boston Globe* in an interview with Mr. Johnson this fall. He will not be the Director of the Museum, said Mr. Johnson; "the role of the President," he said, "is providing a policy framework and then giving the Director and his associates full support in reaching those policies. . . . The President is . . . the means by which the professional staff can accomplish the high goals it ought to have."

Mr. Johnson's first goal? "How can we make it an easy place to go and a less forbidding facade?" he replied.

Problems? Plenty. "The great excitement in museums is the artistic, the aesthetic, and

the educational," said Mr. Johnson, "just as it is in a private university. But we've got to solve the financial problems or none of the rest is possible. . . . Every private institution in a period of inflation is under severe pressure."

And one series of problems with which Mr. Johnson did not deal. Perry Rathbone, 15-year-Director of the Museum, resigned in 1972 and his successor, Merrill Rueppel, resigned eight months ago "amidst mounting discontent," as Mr. McGilligan put it, "about his policies." So Mr. Johnson's first problem will be to preside over the process of choosing the man who will, as new Director, oversee the museum's "next chapter."

M.I.T. has had a major role in the Museum of Fine Arts ever since the Museum's founding 105 years ago. Indeed, William Barton Rogers, who founded M.I.T., was one of the organizing founders of the Museum; two others were the Presidents of Harvard and of the Boston Athenaeum. ☐

Killian Award

Frank Press, Robert R. Shrock Professor of Geophysics who is Head of the Department of Earth and Planetary Sciences, holds the 1975 James R. Killian, Jr., Faculty Achievement Award, and he will deliver a series of Killian Lectures in the spring. The citation to Dr. Press says he brings to the Lectureship "the authority of one who is making important contributions through his own teaching and research, an adviser to government, and a leader in international cooperation"; the first qualification refers to his work in seismology, the second to his membership on the National Science Board, and the third to his interest in geology and seismology in the U.S.S.R. and China. ☐

Individuals Noteworthy

Kudos: Honors, Awards, Citations

To **Malcolm L. Gefter,** Associate Professor of Biochemistry at M.I.T., the 1975 Pfizer Award in Enzyme Chemistry of the American Chemical Society . . . to **John S. Waugh,** Sc.D. '60, Professor of Chemistry at M.I.T., the 1976 Irving Langmuir Award in Chemical Physics of the American Chemical Society . . . to **Ali Javan,** Professor of Physics at M.I.T., the 1975 Frederic Ives Medal, the highest award of the Optical Society of America . . . to **Charles Stark Draper,** '26, the 1974 Lord Kelvin Gold Medal of the (British) Institution of Civil Engineers . . . to **Elias J. Corey,** '48, the $10,000 Arthur C. Cope Award for 1976 of the American Chemical Society.

To **Gordon L. Brownell,** Ph.D. '50, Professor of Nuclear Engineering at M.I.T., the Paul C. Aebersold Award of the Society of Nuclear Medicine . . . to **Richard P. Kotelly,** '56, a Bronze Medal for Commendable Service of the U.S. Environmental Protection Agency . . . to **Edward Woll,** '35, the Alexander Klemin Award, the highest honor of the American Helicopter Society . . . **Robert A. Leonard,** M.A. '57, was elected a member of The Young Presidents' Organization of New Jersey, an international organization inspiring its members through education and idea exchange . . . **Irwin I. Shapiro,** Professor of Geophysics and Physics at M.I.T., is among 46 scientists elected Fellows of the American Physical Society.

Three M.I.T. alumni were honored at the A.I.A.A./A.S.M.E./S.A.E. Structures, Structural Dynamics and Materials Conference last May: to **David Bushnell,** '60, the Structural Mechanics Research Award of the Office of Naval Research and the American Institute of Aeronautics and Astronautics . . . to **James E. Ashton,** Ph.D. '67, the Structures Design Lecture Award of the A.I.A.A. . . . to **Theodore H. H. Pian,** Sc.D. '48, the Structures, Structural Dynamics and Materials Award, which is annually presented at the conference.

John S. Dancz, Research Associate in the M.I.T. Department of Chemistry; **Samuel L. Myers,** Ph.D. '75; and **Fred C. Schweppe,** Professor of Electrical Engineering at M.I.T., received Fulbright-Hays awards for university lecturing and advanced research for the 1975-76 academic year . . . to **Joe M. Rife,** '66, the Teter Award of the Society of Automotive Engineers. Mr. Rife also took office as Chairman of the New England section of that same society.

Three alumni who are faculty members at Northwestern University's Technological Institute have received recognition: **Jerome B. Cohen,** '54, was named United States co-editor of the Journal of Applied Crystallography . . . **Gustave J. Rath,** '52, named a Fellow of the Institute of Medicine of Chicago . . . **Ross B. Corotis,** '67, was appointed newsletter editor for the American Society of Civil Engineers in the Engineering Mechanics Division.

Hans C. Anderson, '62, was selected a University Fellow at Stanford University for 1975-77 . . . to **William J. Gallagher,** '50, the award of Fellow of the American Society for Quality Control "for early perseverance in introducing methods of statistical quality control in the automotive industry; and his genuine leadership in the Greater Detroit Section and the Automotive Division."

Counselors: Officers, Directors, and Advisors

Lawrence C. Turnock, Jr., '41, Assistant to the Financial Vice President of Republic Steel Corp., has been elected Executive Vice President of the American Iron Ore Association . . . **Gerald G. Probst,** S. M. '56,

elected to Executive Vice President of Sperry Rand Corp. . . . **Daniel Brand,** '58, to Undersecretary of the Executive Office of Transportation and Construction of the Commonwealth of Massachusetts . . . **Edwin L. Hobson,** '37, to President and Director of Aladdin Synergetics, Inc. . . . **J. K. Jamieson,** '31, retired from his position as Chairman and Chief Executive Officer of Exxon Corp. and will remain a director.

Harlan McClure, M.Arch. '41, Dean of the College of Architecture at Clemson University, was chosen a judge in the 1975 Architectural Awards of Excellence Competition sponsored by the American Institute of Steel Construction . . . **Anthony Ralston,** '52, Professor and Chairman of the Department of Computer Science at the State University of New York at Buffalo, was elected President of the American Federation of Information Processing Societies, Inc. . . . **Raymond J. Woodrow,** '36, Assistant for Special Studies at Princeton University, to the Board of Directors of the Research and Development Council of New Jersey.

Bruce D. Murray, '53, to Director of the Jet Propulsion Laboratory in Pasadena, Calif. . . . **Henry H. Perritt, Jr.,** '66, to Deputy Undersecretary for Economic Policy Review of the U.S. Department of Labor . . . **Denis A. Blackett,** '60, to the Massachusetts Port Authority Board of Directors . . . **Arnold Gangnes,** M. Arch. '46, Seattle architect and authority in architectural design for the handicapped, has been appointed to the President's Committee on Mental Retardation . . . **William A. Davis, Jr.,** Associate Professor of Law and Urban Studies at M.I.T., appointed to a two-year term as a director of the newly created Commonwealth of Massachusetts Government Land Bank . . . **Robert B. Anderson,** S.M. '66, to President of a new subsidiary company of the Sun Oil Co.

Percy L. Nelson, '47, to Vice President of the Corporation of Chas. T. Main, Inc. . . . **Richard B. Marsten,** '45, Director of Communications and Data Management Programs for the National Aeronautics and Space Administration, to Dean of the City College School of Engineering . . . **Alexander J. Tachmindji,** S.M. '51, to Chief Scientist of MITRE . . . **Sidney Howell,** '49, Executive Vice President of The Weatherhead Co., Cleveland, Ohio, to Director of the National Fluid Power Assoc.

Fujio Matsuda, Sc.D. '52, President of the University of Hawaii, has been elected to the boards of directors of both UAL, Inc. and its subsidiary, United Airlines . . . **Felix J. Conti,** '34, President of T & B Construction, Inc., of Somerville, has been elected Vice President of the Associated General Contractors of Massachusetts, Inc. . . . **Margaret L. A. MacVicar,** '64, Associate Professor of Physics at M.I.T., to the Board of Directors of the Sprague Electric Co.

Moving Up in Academe

William G. Guindon, S. J., Ph.D. '48, to Dean of the Jesuit School of Theology in Chicago . . . **Robert E. Kelly,** Sc.D. '64, to Professor in the Department of Mechanics and Structures in the School of Engineering and Applied Science of U.C.L.A. . . . **Frederick L. Orthlieb,** '68, Assistant Professor in the Department of Engineering at Swarthmore College . . . Three young M.I.T. faculty members appointed to Esther and Harold E. Edgerton Assistant Professors for two years are: **Alan J. Grodzinsky,** '71, Assistant Professor of Electrical Engineering and Computer Science; **Robert E. Cohen,** Assistant Professor of Chemical Engineering; and **David G. Holmes,** Ph.D. '73, Assistant Professor of Mechanical Engineering.

Items of Interest

Earthquake prediction has reached new dimensions in the past decade. Major contributors from M.I.T. mentioned in the *Time* magazine Sept. 1, 1975 cover story, "Forecast: Earthquake" are: **John Healy,** '51, U.S. Geological Survey scientist; **Lynn Sykes,** '59, head of the seismology group of Columbia University's Lamont-Doherty Geological Observatory; **William Brace,** '46, Professor of Earth and Planetary Science at M.I.T.; **Christopher Scholz,** Ph.D. '67, of Columbia's Lamont-Doherty Observatory; **Amos Nur,** Ph.D. '69, of the Department of Geophysics at Stanford University; and **Frank Press,** Professor of Earth and Planetary Science and head of that department at M.I.T.

W. Daggett Norwood, '23, has authored a new book, *Health Protection of Radiation Workers,* published by Charles C Thomas.

Career Changes

Thomas C. Buchanan, '50, to Director of Marketing of The Milford Rivet and Machine Co., Milford, Conn. . . . **Clifford L. Noll,** '49, to Western Regional Manager of Equipment and Fired Heater Sales for Foster Wheeler Energy Corp., Livingston, N.J. . . . **John R. Hodson,** S.M. '50, has joined Steuber Co., Inc., New York, as Manager of Special Projects . . . **Adolph L. Sebell,** '40, to President of the Housewares and Home Furnishings Division of Dart Industries Inc.'s Consumer Products Group . . . **Gary H. Lantner,** S.M. '72, to General Manager of the Boston South Terminal Corp. at Logan International Airport . . . **Charles E. Craig,** S.M. '72, to General Manager of Bearing Operations for the Canton, Ohio district of The Timken Co. . . . **Steven C. Mason,** '57, to Executive Vice President of the Mead Corp. Paperboard group . . . **Daniel L. Lycan,** '52, to District Engineer of Rock Island, Ill. Corps of Engineers.

Frank B. Sprow, '62, to Technical Manager of Exxon's Bayway Refinery in Linden, N.J. . . . **Louis B. Peloubet,** '49, to Controller of Union Carbide Corp., New York City . . . **Richard D. Cummings,** '61, to Executive Vice President of Daystar Corp., Burlington, Mass. . . . **Robert W. White,** '55, to Director of Facilities Management at the Electric Boat Shipyard, Groton, Conn. . . . **Richard Weinstein,** '59, to Assistant Ex-

To Edward Woll, '35 (right), the Dr. Alexander Klemin Award of the American Helicopter Society "for his leadership in design and development of jet engines and his prime influence in overall design of the U.S. Army T700 turboshaft engine to power advanced helicopters of the 1980s." It's the foremost award of the Society, presented here by James F. Atkins, President of Bell Helicopter Co.

ecutive Officer to the Associate Administrator for Center Operations, N.A.S.A. headquarters, Washington, D.C. . . . **William L. Demiene,** M. Arch. '57, to Chief Architectural Designer at Albert Kahn Associates, Inc., Detroit, Mich. . . . **Paul H. Ekberg,** '59, to Manager of Republic Steel Corp.'s Chicago District.

Raymond F. Winch, S.M. '59, to Vice President of a new industrial marketing company of the Sun Oil Co. . . . **James G. Kaiser,** S.M. '73, to Business Planning Manager in the International Consumer Division of Corning Glass Works . . . **Ferdinand G. von Kummer,** '48, to Vice President and General Manager of A.B. Dick Co.'s International Division . . . **Franklin S. Atwater,** '38, to President of the Homelite Division of Textron, Inc., Providence, R.I. . . . **William R. Moser,** Ph.D. '64, to Research Associate in the Department of New Technology of the Badger Co., Inc., a subsidiary of Raytheon . . . **G. Fred Colusso,** '47, to Manager of Licensing for Europe for Combustion Engineering International . . . **Alan J. Roberts,** M.S. '53, to Technical Director at the MITRE Corp. . . . **Gerald P. Langelier,** '53, will head the newly-formed Airborne Systems Analysis and Test Department of MITRE. . . . **Ralph N. Bussard,** S.M. '69, to Manager of Management Advisory Services in their Atlanta office . . . **Jorge Luis Cowley,** S.M. '73, to Transit Administrator for the City of Raleigh, N.C., heading the city's new Mass Transit Division . . . **John T. Vieira,** S.M. '65, to Principal of the Susan H. Wixon School, Fall River, Mass.

Walter L. Threadgill, '41, to Manager of Design Engineering of the Rust Engineering Company, in Baton Rouge, La. . . . **C. Nicholas Pryor,** '60, to Technical Director of the Naval Underwater Systems Center . . . **Rodney I. Frost,** '52, to Manager of Ceramic Process Development of Corning Glass Works, Corning, N.Y. . . . **Thomas Linkas,** '69, to Assistant Vice President of The Putnam Management Co., Inc., Boston, Mass. . . . **Gary M. Stuart,** '62, to Assistant Treasurer of General Foods Corp., White Plains, N.Y.

Carl H. Cathey, Jr., S.M. '65, Director of Reconnaissance and Electronic Warfare in the Office of the Deputy Chief of Staff for Research and Development at the Pentagon, has been promoted to brigadier general . . . **Edward L. Belcher,** '46, to President of Caldwell Manufacturing Co., Rochester, N.Y. . . . **Daniel Strassberg,** S.M. '58, to Engineering Manager of the Analog Modules Department of Analog Devices, Inc., Norwood, Mass. . . . **Philip D. Blanchard,** '24, to Vice President of Engineering and Development of Wyatt, Inc., New Haven, Conn. □

Administrative Changes at M.I.T.

Weston J. Burner, at M.I.T. since 1969, is now Director of the Office of Administrative Information Systems as well as of the Information Processing Center; it's a move toward consolidation of functions and services in the interest of economy and efficiency, says Robert H. Scott, Director of Information Processing Services . . . **David Colley,** formerly Associate Professor of Graphic Design at the University of Illinois, has joined the M.I.T. Design Services to work on publications of the Alumni Association . . . **Claudia B. Liebesney** is Assistant Director of Personnel Services; she has been Personnel Officer for departments reporting to the Provost . . . **Michael F. Luck,** Assistant Director of the Development Office, has been promoted to Director; the new job gives him "broad support responsibilities" for the M.I.T. Leadership Campaign . . . After 30 years of association with the M.I.T. Admissions Office, **Julia C. McLellan** has become Associate Director of Admissions; she'll be increasingly involved with special recruiting programs for women and minorities . . . **John E. Newcomb, Jr.,** Personnel Officer since 1967, is now Assistant Director for Administration at the Center for Advanced Engineering Study . . . **Pamela Walker Turner,** S.M. '71, has joined her alma mater as Director of Recruitment and Placement . . . **William J. Westcott,** since 1972 Administrative Assistant in the Department of Electrical Engineering, is Administrative Officer of the Department of Mechanical Engineering . . . **Gail P. Wilson,** former Educational Counselor in the Atlanta Urban Corps, Georgia State University, is Assistant to the Director of Admissions. □

Martin M. Phillips, 1924-1975

M. M. Phillips

Martin M. Phillips, '47, Regional Director of the M.I.T. Alumni Association, died suddenly while in Miami, Fla., on Alumni Association business on October 4. He was 51.

Mr. Phillips returned to M.I.T. after a distinguished business career to be Assistant Director of the Alumni Fund in 1970; his assignment as Regional Director with responsibilities for alumni in the southern states began on July 1. Paul E. Gray, '54, Chancellor, described him as "extraordinarily professional in all his work in behalf of M.I.T. The community benefited by both his presence and his efforts."

In 1960, after he had filled management assignments with Goodyear Tire and Rubber Co., the Charles S. Draper Laboratory, and Itek Corp., Mr. Phillips helped form Tyco, Inc., in Waltham, Mass., where he was Vice President and Secretary; he also served as President and Director of Data Sciences, Inc., and Treasurer and Director of Triconix, Inc., both Tyco subsidiaries. Five years later he became Vice President of BTU Engineering Corp., where he directed the design and manufacture of electric processing furnaces.

Mr. Phillips had been active in M.I.T. alumni affairs almost continuously since graduation, and he had won the respect and admiration of many alumni. He had also maintained an interest in student affairs, and many students speak with warmth of the hospitality they had found in the Phillips' home. □

Malcolm G. Kispert, 1923-1975

Malcolm G. Kispert

Malcolm G. Kispert, '44, who held a series of major administrative posts at M.I.T. since receiving his Master's degree in aeronautical engineering in 1946, died of an apparent heart attack at his home in Dover, Mass., on September 13. He was 52.

President Jerome B. Wiesner spoke for the Institute in remembering "with gratitude and deep appreciation Mr. Kispert's many contributions to this institution. And we shall remember him equally for his warm friendship, great good humor, and capacity for human understanding and compassion," said Dr. Wiesner.

At memorial services in the M.I.T. Chapel on September 17, James R. Killian, Jr., '26, with whom Mr. Kispert had been intimately associated in the Institute administration, referred to his "dignity, sensitivity and skill." Mr. Kispert had "exceptional administrative gifts," said Dr. Killian, and M.I.T. "has reason to be deeply indebted to him."

Howard W. Johnson, Chairman of the M.I.T. Corporation, had similar praise for Mr. Kispert's "high competence and great skill. . . . In representing the Institute to alumni and others throughout the country, Mr. Kispert was an ardent ambassador for M.I.T. and for the cause of private higher education," said Mr. Johnson.

Mr. Kispert, a native of Fall River, entered M.I.T. in 1940. He served in the U.S. Navy during World War II, then returned to the Institute for graduate studies which culminated with his appointment as assistant to the late Karl T. Compton, then President of the Institute. By 1952, when Dr. Killian was President, Mr. Kispert became Executive Assistant to the President; later he was Assistant Chancellor (1956), Administrative Vice Chancellor (1957), and Vice President — Administration (1961).

As Institute Secretary since 1971, Mr. Kispert was concerned with marshalling new resources for the long-term support of the university.

The family requested that contributions in Mr. Kispert's memory be made to scholarship funds at M.I.T. □

Alfred L. Loomis, 1887-1975

Alfred L. Loomis, a widely known financier, physicist, and lawyer, died at his home in East Hampton, Long Island, on August 11. At 87, he was the eldest member of the M.I.T. Corporation.

Awarding him an honorary degree in 1933, Yale University — his alma mater — called Mr. Loomis "the 20th-century Benjamin Franklin" — a way of recognizing his diverse interests and attainments. After graduating from Yale in 1909 Mr. Loomis attended Harvard Law School and, beginning in 1912, developed a successful career in law and finance. But by the 1930s his interests were turning increasingly to science, which had been his field at Yale.

Prior to World War II, as Chairman of the Microwave Committee of the National Defense Research Committee, Mr. Loomis was influential in the decision to establish the Radiation Laboratory at M.I.T. to carry out the development of radar. He was also a founder of the Loomis Institute for Scientific Research and of the Rand Corp., and he was influential in establishing the Lawrence Radiation Laboratories at the University of California (Berkeley).

Mr. Loomis first became a member of the M.I.T. Corporation in 1931, just as he was retiring from business to devote full time to scientific interests, and during the next few years he worked with President Karl T. Compton to develop M.I.T.'s growing programs in science and basic research. He became Life Member Emeritus in 1962. On learning of Mr. Loomis' death, Howard W. Johnson, Chairman of the Corporation, said that "M.I.T. and the scientific community have lost a distinguished colleague and benefactor"; he called Mr. Loomis "a national leader in the furtherance of basic research." □

Paul C. Eaton, 1905-1975

Paul C. Eaton, '27, who taught English at M.I.T. from 1930 to 1942 and after World War II went on to become Dean of Students at the California Institute of Technology, died in Portland, Maine, on September 18. He was 69.

Dean Eaton studied English literature at Harvard (M.A. 1930) after completing his M.I.T. degree in business and engineering administration. As a member of the U.S. Naval Reserve he served in both Atlantic and Pacific theaters during World War II, and at the end of the war he became Associate Professor of English Literature and Assistant Dean of Students at Caltech. Dean Eaton retained close associations with M.I.T. colleagues throughout the years, travelling each summer to a vacation home in Kennebunkport. □

Philip A. Knight, 1936-1975

Philip A. Knight, Personnel Officer in the Office of Personnel Services, died on August 9 as a result of injuries sustained in an automobile accident. He was 39.

Mr. Knight came to M.I.T. in 1969 as a Senior Technician in the School of Engineering; he had graduated from Boston Technical High School in 1963 and served with great distinction for five years in the U.S. Navy. His appointment to the Office of Personnel Services was in 1973. □

The late Uncas A. Whitaker, '23 — he died suddenly on September 16 — took special interest in the life sciences at M.I.T. and special pride in the Institute's Health Science Fellowships. Here he is (center) during a campus visit early this year to meet five of the Fellows: (left to right) Stephen C. Jones, S.M. '73, Jay J. Schnitzer, Dusan G. Lysy, Chester H. Conrad, '72, and David W. Levine, '70.

Uncas A. Whitaker, 1900-1975

Uncas A. Whitaker, '23, founder and Chairman of the Board of AMP, Inc., a leading international firm in the design and manufacture of electrical components, who was a Life Member Emeritus of the M.I.T. Corporation, died in Swans Island, Maine, on September 16. He was 75.

Mr. Whitaker had been a member of the M.I.T. Corporation for 14 years, and during that period he had been influential — both through his intellectual interests and generous philanthropic support — in the development of the life sciences, biomedical engineering, and medical education at M.I.T. Irwin W. Sizer, Dean of the Graduate School Emeritus who formerly headed the Department of Biology, called Mr. Whitaker "one of the greatest friends M.I.T. has ever had."

In 1965 Mr. Whitaker's name was given to a new building then just completed to double the space available at M.I.T. for work in the life sciences. Since then, he had provided initiating support for the Joint Harvard-M.I.T. Program in Health Sciences and Technology and he had established the Whitaker Professorship in Biomedical Engineering, currently held by Robert W. Mann, '50, of the Department of Mechanical Engineering.

Mr. Whitaker's M.I.T. degree was in mechanical engineering; later, while employed at the Westinghouse Air Brake Co. in Pittsburgh, he completed the B.S. degree in electrical engineering at Carnegie Institute of Technology (1929), and still later, while working at the Hoover Co. in North Canton, Ohio, he received the J.D. degree from the Cleveland Law School (1935).

It was in 1941, after three years as Director of Research and Engineering at American Machine and Foundry Co. in New York, that Mr. Whitaker founded Aircraft-Marine Products, Inc., in Harrisburg, Penn. Under his leadership that company rose to international importance as a producer of electromechanical connectors, and he continued an active role in its management until his death.

Speaking at a memorial service, Howard W. Johnson, Chairman of the Corporation, paid tribute to Mr. Whitaker as "one of those rare and unusual leaders who created and sustained his own company and made it an economic force of great quality and distinction for the benefit of others." □

Steven Drazovich, 1956-1975

Steven Drazovich, '78, a sophomore who had yet to choose a major field of study at M.I.T., died while mountain climbing with the M.I.T. Outing Club in the White Mountains on October 4. He was 19.

Mr. Drazovich and his colleagues were climbing a slope that the Outing Club rates as "an easy fifth class — a step or two up from an ordinary mountain hike," according to Robert W. Milne, '78, Outing Club President. "He was in a section that was well within his experience," Mr. Milne said, "and he had done a good deal of climbing before this." But somehow Mr. Drazovich slipped while on White Horse Ledge, slid down a gully, and was struck by a boulder.

James J. Bishop, Associate Dean for Student Affairs, told *The Tech* that "the accident was just not preventable. I was very impressed with how competently and professionally the incident was handled," he said.

Mr. Drazovich was a native of Rock Springs, Wyo. Baker House friends described him as "an athletic person who liked mountain climbing," and they said he was well known and liked throughout the House. □

Willard E. Edwards, 1903-1975

Willard E. Edwards, '26, who rose to the rank of Lieutenant Commander in the U.S. Navy and devoted his retirement years to an unceasing promotion of his "perpetual calendar," died of a heart attack while touring in Canada on August 15. He was 72.

Commander Edwards was a native of Quincy and studied at M.I.T. for three years before transferring to the University of Oklahoma for his B.S. degree (1929). He served in the U.S. Navy from 1941 to 1953, and before and after military service was associated with a number of major firms in electronics and radio telephone research and development.

The most significant feature of Commander Edwards' calendar is that every weekday falls on the same date of every month; in other words, Monday is always the first, eight, 15th, or 22nd of the month. The year is composed of 364 days, with holidays added as necessary. Last year the United Press called Commander Edwards' promotion of his calendar "the greatest one-man campaign ever made for any cause." □

Deceased

Thomas F. Geraghty, '05; August 31, 1975; 420 Linden, Wilmette, Ill.*
Walter B. Kirby, '07; July 19, 1975; Riga Bldg. #8, Salisbury, Conn.*
Ralph F. Knight, '07; August 20, 1975; 81 Lovett St., Beverly, Mass.*
Denison K. Bullens, '09; June 28, 1974
Alfred Hague, '10; October 19, 1975; 631 S.W. 6th St., #804, Pompano Beach, Fla.
William M. Schofield, '10; 1950; Box 121, Akron, Ohio
Franklyn M. Stibbs, '11; June 23, 1975; Heritage Village, Apt. 44D, Southbury, Conn.
John M. Hargrave, '12; July 16, 1975; P.O. Box 857, Thomasville, Ga.
Charles A. Bidwell, '15; September 1, 1975; 485 Rafael Blvd., Saint Petersburg, Fla.
Louis H. Young, '15; August 31, 1975; 233 Grove St., Auburndale, Mass.*
Marion L. Cousens, '18; May 29, 1975; 204 St. David Ct., Cockeysville, Md.*
Donald C. Gogg, '18; July, 1975; 186 Atlantic Ave., Marblehead, Mass.
Ray H. Bartlett, '19; May 20, 1975; 4485 N.W. 17th Terr., Ft. Lauderdale, Fla.
Arthur Roberts, '20; July 18, 1975; 212 N. Main St., Chagrin Falls, Ohio*
Algot J. Johnson, '21; May 26, 1975; 277 Washington St., Gloucester, Mass.
Victor S. Phaneuf, '21; July 16, 1975; 8352 Candlewood, Largo, Fla.
Joseph Wenick, '21; August 21, 1975; 37 Cedars Rd., Caldwell, N.J.*
Eaton H. Perkins, '22; August, 1975; 80 Ardsmoore Rd., Melrose, Mass.*
Charles G. Ball, '23; July, 1975; 8 Legion Rd., Weston, Mass.
Gabriel J. Lund, '23; December 31, 1973; Skogueien 14, 3250 Lavick, Norway
Sidney W. Andrews, '25; June 23, 1975; 974 Highland Ave., Pelham, N.Y.*
Edward W. Carlton, '25; June 25, 1975; 2587 S. Westgate Ave., Los Angeles, Calif.
Bradford P. Young, '26; August 6, 1975; 4826 E. Waverly St., Tucson, Ariz.
Wilmer L. Barrow, '29; August 29, 1975; Mirror Lake, N.H.*
George G. Mintz, '29; May 22, 1972
James A. Bain, '30; October 9, 1973; 133 Brook St., Framingham, Mass.
John Alden Pratt, '30; August 24, 1975; Box 266, Castine, Maine
Duke Selig, '33; April 4, 1975; 5615 Doliver Dr., Houston, Tex.
Alfred W. Wilmann, '33; August, 1975; 165 Clifton St., Belmont, Mass.
Jack I. Hamilton, '36; July 19, 1975; 3265 Belvoir Blvd., Cleveland, Ohio*
Joseph M. Vallone, '38; July 6, 1975; 54 Poppy Dr., Cranston, R.I.*
David A. Bartlett, '39; July 22, 1975; 2300 Riverside, Tulsa, Okla.*
Frederic P. Fischer, '39; June 23, 1975; 5005 Glenwood Dr., Williamsville, N.Y.
James S. Luckett, '40; May 26, 1974; 1941 S. Hull St., Montgomery, Ala.
William C. Burrage, '43; June 19, 1972; Box 669, Warrenton, Va.
James L. Newmeyer, '43; July 19, 1975; 5280 S.W. 76th St., Miami, Fla.
Malcolm G. Kispert, '44; September 13, 1975; 5 Sterling Dr., Dover, Mass.
Durja S. Bajpai, '46; November, 1969; Bombay, India
Richard A. Potter, '47; August 27, 1975; 1091 Bellmar Dr., Mansfield, Ohio*
W. Ross Bowen, '48; August 30, 1975; Camp Lee Rd., Epping, N.H.
Norman M. Klein, '49; June 27, 1975; 3213 Macomb St. N.W., Washington, D.C.*
Malcolm Basche, '51; June 25, 1975; 178 W. Ridge Dr., West Hartford, Conn.
Curtis H. Snow, '51; August 18, 1971; 47 MacMillan Dr., Brunswick, Maine
William C. Shapiro, '53; July 28, 1974; West Pakistan
John W. Lyons, '57; July 13, 1975; 11 Benton Rd., Belmont, Mass.
Diana Collins Donald, '58; August 9, 1975; Main St. R.F.D. #2, Farmington, Conn.
Russell R. Pfeiffer, '60; April 5, 1975

* Further information in *Class Review*

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Richard O. Elliot, our sole survivor, is still enjoying his Maine weather and visits from family and friends. To all the friends and progeny of '96 go wishes for a happy holiday season. — **Clare Driscoll,** Acting Secretary, Cliff St., Plymouth, Mass. 02360

99

Your Secretary was in New Hampshire for ten days in August and during that time I went to see **Carroll Brown** whom I had not seen for two years. I found him well and sitting out on the porch of his home at Rye Beach, N.H. I enjoyed my call because shortly he was to celebrate his 97th birthday. — **Norman E. Seavey,** Acting Secretary, Apt. 1115, Westminster Towers, Orlando, Fla. 32801

03

Our mature classmates, though not eligible for present scholarships, should urgently inform our grandchildren or great-grandchildren of our unused multi-thousand dollars in gifts to M.I.T. for such future use. And then we'll perpetuate the tradition of 1903.

Our Happy Birthdays list of classmates is exultantly portrayed: **Robert W. Daniels,** II, September 3, 1880; Mrs. **Ferrucio Vitale,** VII, September 28, 1883; Miss **Mary N. Phillips,** VII, October 17, 1876; and **Jay B. Simon,** III, October 29, 1879. — **John J. A. Nolan,** Secretary-Treasurer, 13 Linden Ave., Somerville, Mass. 02143

05

The sad news that **Thomas F. Geraghty** died on August 31, 1975 is contained in a letter from his son, Thomas F. Geraghty, Jr. (135 South La Salle St., Chicago, Ill. 60603). I have no further details at this time.

Peggy and I enjoyed our summer vacation. We were in North Carolina for a month then in the New York/New Jersey area visiting friends and relations until the middle of September. It was disappointing but impossible for us to get up to Cambridge to attend the festivities.

When you read these notes, it will be approaching the Christmas Season. Peggy and I extend our love and best wishes to all. — **William G. Ball,** Acting Secretary, 6311 Fordham Pl., Bradenton, Fla., 33507

07

Walter Bradnee Kirby died July 19, 1975 in Salisbury, Conn.; and **Ralph F. Knight** died on Aug. 20, 1975 in Beverly, Mass. The following excerpts from newsclippings record their numerous accomplishments.

Mr. Kirby had practiced architecture in New York and Connecticut for more than four decades and was 89. He "began his career in New York City in 1912 shortly after returning from study in Italy where he attended the American Academy in Rome. That influential period in his career was made possible by his having won a travelling fellowship in competition at Massachusetts Institute of Technology where he was graduated in 1907 and did graduate work in advanced architectural design in 1908.

"The Italian style influenced his early work particularly when he was associated with Vitale, Brinckerhoff and Geiffert who designed many large estates. Mt. Walley in Brookline, Mass. is an example of the Italian style villa, farm group, gate lodge and garden which Mr. Kirby and his associates designed. Another example is the W. H. Walker estate with its elaborate stone boat landing and greenhouses in Great Barrington, Mass.

"In 1930, Mr. Kirby moved his office and residence to New Canaan, Conn., where he designed many residences, additions to the post office, a number of stores, and the new fire house, a commission he was awarded in open competition. In addition he painted two murals depicting New Canaan in 1834 and in 1934, both installed in the Town Hall auditorium. He designed for the estate of Henry A. Rudkin in Fairfield, Conn., the stone residence, garage, stables, cottage, and gardens which later became famous when Mrs. Rudkin developed Pepperidge Farm Bread. Later he designed the Pepperidge Farm Bakery in Norwalk, Conn. He was a member of the Fairfield County Hunt Club and of Ox Ridge Hunt Club in Darien.

"As a young man Mr. Kirby was a member of Squadron C of the New York Cavalry. In 1916-17 he was called into service and sent to the Mexican border for duty with the U.S. Cavalry. During World War II he volunteered his services and was called to do architectural work for the U.S. Navy's building program for the Brooklyn Navy Yard.

"Mr. Kirby is survived by his sister Dorothy K. Spalding, and a nephew F. Pratt Spalding and his step-daughter Miss Ruth McCreary. His wife Helen Chandler Kirby died in 1966."

From the *Beverly Times*: "Ralph F. Knight, inventor, arbitrator, fisherman and story teller died at the age of 92. Following in his father's footsteps, Ralph enjoyed working with his hands and tinkering with things. His curious mind and 'good hands' led him into a career at United Shoe Machinery Corp. During his 36-year tenure, Knight held more than 17 patents and became head of the experimentation division 'He was a trouble shooter,' said his son Richard A. Knight. 'My father would tackle anything — manufacturing, labor and inventions.'

"Richard Knight said his father began his career building and designing race cars for the Vandenberg races in Connecticut at the turn of the century. Those races later became the focal point for some of his best stories, a talent his son remembers best of all. He would delight the children with stories of sabotage, steam-powered race cars and fearless drivers, his son recalled, adding that a theme in the stories was to eliminate the competition, anyway possible.

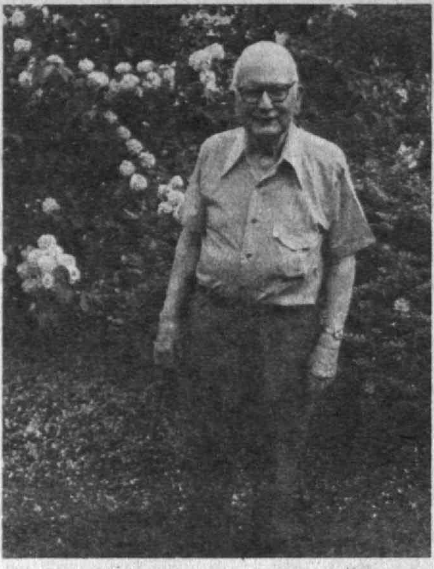
" 'I'm not sure, but I think he invented the first six cylinder gasoline engine,' Knight said. It was not an elaborate affair, and merely consisted of linking two engines together in a clever way, he explained. . . . His father went to Alaska in search of gold bringing back photographs and tales, but no money. He opened a machine shop and began tinkering and learning about machinery.

"Mr. Knight attended Dartmouth College in the horse and buggy days, quit school and started fresh at M.I.T., graduating in 1907. He joined United Shoe Machinery Corp in 1914 and retired in 1950. He was a member of the U.S.M. Quarter Century Club, the last charter member of Budleigh Lodge A.F. and A.M. and the First Federated Church. He is survived by his son and a daughter, Mrs. Alan (Cynthia) A. Lawson of Meguon, Wisc., and seven grandchildren." — S.F.

08

We are sorry to report the death of **Harry P. Sweeny** (91) of 35 Oliver St., Rockland, Maine, on May 12, 1975. A complete report of his work is given in the *Review* of De-

Joe Wattles, '08, has given us a brief manuscript urging that the U.S. should "put all its eggs in one basket" — that is, concentrate on railroad transportation for all long-distance freight. He proposes that a modernized railroad without highway competition could maintain itself, create profits, and attract capital. "The agricultural development of the middle west and the settlement of the far west were the result of rapid extension of the railroads," he writes, and this is no time to abandon the system. Joe adds in a note that his views are the result of many years' living near the New Haven's Shore Line between Boston and Providence; indeed, he travelled on that railroad for his education and since then as a commuter — "a distance equal to twice around the world," according to his calculations. — J.I.M.



The late Ray Wilson, left, and Johnathan Noyes, 1912 Estate Secretary, during their June visit at Ray's home in Swarthmore, Penn.

cember, 1970. His final remark, "a rolling stone but Oh what memories." He was a mining engineer and our oldest M.I.T. graduate.

Now, the oldest graduate is **Frank W. Sharman** (90) an architect, retired at 1216 North Cherry Ave., Tucson, Ariz. Frank was born Nov. 14, 1884. Those still here remember him as attending one of our Reunions at the Melrose Inn some time ago.

The Tech (since 1881) reports that M.I.T. students pay the third highest tuition of any college student in U.S. — **Joseph W. Wattles III,** Secretary, 26 Bullard Rd., Weston, Mass. 02193

11

Class President **Howard Williams** sent information concerning the deaths of two classmates: Ove Collett, '49, wrote him that his father **Ove Collett** died in June of 1970 "after a long and interesting life." . . . Grace Van Alstine wrote that her husband, **Ray Van Alstine** "passed away last July. He was a fine man always." — S.F.

12

I received a letter dated Aug. 28 from Mrs. Ginni Wilson Boari, daughter of our long time faithful class secretary, **Raymond E. Wilson** that reads in part as follows:

"Dad passed away on August 19th. He and I were taking a cruise on the Delta Queen paddlewheeler when he had a cerebral hemorrhage. The captain was kind enough to dock the boat at Paducah, Kentucky where an ambulance was waiting to take us to a hospital. He died late that afternoon. He spent his last day actively and very happily on the boat trip he wanted to take so much, and his life was wonderfully full and productive. We are grateful it was not a long illness."

I had the pleasure of being Ray's house guest at Swarthmore, Penn. for three days in early June. Ray got out his carefully cataloged slides of pictures that he took at most of our five-year class of 1912 reunions so we relived together some of the old days with many a chuckle.

Ray was both diligent and conscientious as our 1912 class secretary and he will be greatly missed. Yours Truly, **Jonathan A. Noyes,** 320 Dunn St., Bryan, Tex. 77801

13

To all the members of the Class of 1913, we wish you a Merry Xmas and a Happy New Year. We appreciate a letter from **Henry Glidden** enclosing a clipping honoring Burton Cushing and we quote: "**Burton L. Cushing** of 214 Howard St., a member of the Rockland C. of C. for 61 years, was honored by the chamber with a presentation of a plaque and a life membership in the organization. Cushing began his long association in 1914 when he was proposed for membership by his father who was a foreman at the Rice and Hutchins Shoe Factory. Cushing noted that members of the Rockland Chamber at that time included E. T. Wright, Jim Spencer and other noted entrepreneurs of the early 1900s. In reminiscing on the past 61 years, two-thirds of the existence of the chamber that began in 1882, Cushing said that the chamber has met in G.A.R. Hall, V.F.W. Hall, Channing Hall, and in local restaurants. Mr. Cushing was given a standing ovation by chamber members." Henry wrote: "**Burt L. Cushing,** is just about Mr. Rockland! The article does not mention that he is on the Board of the Rockland Library, too. . . . After **Ward Lovell** died, I wrote Mrs. Lovell, only to have the letter returned by the Post Office. The address I used was the place where Jane and I dropped in on the Lovell's not long ago — Kingston. Ward and I were at Rindge Tech together as well as M.I.T."

We received a note from **Paul Cogan**'s widow, Arlyle: "I am the sender of sad news — my dear husband, Paul, died July 19, 1975. He was very ill from November, 1974, yet always planned and hoped to get to the next reunion of the class of '13. Many times he spoke of you and the great job you were doing for the Class of '13 and all the classmates. Thought you would like to know this."

Gordon Howie's daughter, Laura, of Worcester, Mass., informed us of Gordon's condition and we quote: "I thought I had better write you about my father's condition. Gordon Howie had a stroke April 18 and was in the hospital until May 23. Then he was transferred to a nursing home and was progressing slowly until August 26, when he was taken back to Morton Plant Hospital with a high fever. He was in intensive care for two days and now is in a room. The stroke paralyzed his left side and affected his swallowing. After 12 weeks he was able to eat meals and had reached the point where he was almost on regular food. He walked once a day with the therapist, and could move his hand a little. I was able to be in Clearwater from July 3 to August 22 and had good visits with him twice a day. My brother, Donald, lives in St. Pete and he and his wife have taken good care of Dad. Dad enjoyed receiving short notes at the nursing home from his many friends and would dictate letters to me that he could sign in return. I hope the hot summer was not too much for you."

Well! The M.I.T. Alumni Officers Conference was held on Campus September 12 to 13, 1975. The Class of 1913 was very well-represented by **Henry Glidden,** Class President; **Charlotte Sage,** Vice President; and **Francis Achard,** 1913 member of the Alumni Association Council. Frank has an almost 100 per cent attendance record. **Henry Glidden** wrote: "Janie and I attended the Alumni Officers Conference at M.I.T. on Saturday. Charlotte Sage and Francis Achard were there also. The box lunch precedent was forgotten this time and a very good lunch was served, which everyone appeared to enjoy in Walker Memorial. I was glad that Jane could see Walker, especially the big mural paintings on the walls. M.I.T. 1913 is not very well represented these days — only four of us, and one not an alumna."

Charlotte Sage advises: "We missed you at the A.O.C. I went over with the Gliddens on Saturday, as Heinie may have written you. Lunch was fine and presentation of awards handled beautifully by Richardson. The enclosed was sent to me by Adelaide Sundin, '47. We have one newsworthy gal!

Hope you are both comfortable and snuggling in for the winter."

Our gal **Marion Rice Hart** has again made the headlines nationally as well as in publications from Ireland. The Boston *Herald American* gave her a first page write-up and we quote: "Woman, 83, Flies Atlantic Alone — Shannon Airport, Ireland — 83 year-old Mrs. Marion Hart of Washington, D.C., landed her single-engined Beechcraft at this international airport yesterday after flying solo across the Atlantic. Mrs. Hart, according to officials of Aer Rianta, the Irish government's aviation authority, is the oldest woman to fly the ocean alone. She made the trip in hops from Washington to Gander, Newfoundland, then on to Reykjavik, Iceland, before heading for Shannon. Before taking off for Dublin for a stopover, Mrs. Hart told newsmen she did it all for fun. She said she was heading for the Middle East in a couple of days but wasn't sure of her final destination."

We are indebted to Heinie Glidden, Charlotte Sage, and **Warren Clancy** for supplying us with various clippings. Again the daily *Herald* added a report from Ireland and we quote: "Grandma's Flight to Mideast Put Off — Dublin. America's flying grandmother, Marian Hart, 83, who flew the Atlantic solo in her single-engined Beechcraft stayed in her hotel room yesterday at Dublin's airport hotel with a slight chill. Mrs. Hart of Washington, D.C., said she would not be flying to the Middle East, as she planned, for a couple of days."

The Capens signing off — **George Philip Capen,** Secretary and Treasurer; Rosalind R. Capen, Assistant Secretary; Granite Point Road, Biddeford, Maine 04005

14

Robert V. Townend died on August 22, 1975; at the age of 83, in Morristown, N.J., where he had lived for 22 years. Bob received his bachelor's degree in Course X, and for two years after graduation was an assistant at the Institute, first in chemistry and then in chemical engineering. During the next ten years he held positions with companies in New York and New Jersey, and in 1926 became professor of chemistry at the University of Delaware. In 1927 a doctor's degree was conferred on Bob by the Johns Hopkins University. In the following 11 years he continued to work in chemical engineering, and did research on uranium for the U.S. Atomic Energy Commission during World War II. Bob became technical supervisor of inorganic research for the General Chemical Division of Allied Chemical Corporation in 1948. The importance of his work there led his employer to ask him to continue in it until he reached the age of 69. During his career he was granted many patents, and did research in Germany. Upon his retirement, he had already planned the Mediterranean cruise which he and Mrs. Townend took the next spring. They took other good trips until 1972, when Bob's health began to decline. Many of us will remember the interesting reports on his travels which Bob thoughtfully provided for our class news. He was a thoroughly loyal Institute alumnus, and, as an honorary secretary, interviewed prospective students for 35 years. In 1916, Bob married the former Lucy Maude Morse. They were both at our 50th reunion. In addition to Maude, Bob left two daughters, Mrs. Donald L. Deininger, of Atlanta, and Mrs. Alex E. Kovacs, of Baton Rouge; a brother, Russell P. Townend, of Denver; a sister, Mrs. Arthur H. Christmann of Riverdale, N.Y., and six grandchildren. — **Charles H. Chatfield,** Secretary, 177 Steele Rd., West Hartford, Conn. 06119

15

We have another sad loss. After a long illness and hospitalization, **Louie Young** died September 3 in Auburndale, Mass. Louie had always been an active and generous supporter of all Class and alumni activities and gave our Class address in the M.I.T. Great Court for our 25th Reunion. At the Gillette Co. Louie was instrumental in plant reorganization. He was later named Plant Superintendent and in 1943 was promoted to Vice President and named a Director. Louie was outstanding in his work for Gillette and is credited with inventing the blade dispenser and various blade testing machines used by Gillette. Representatives of our class attended Louie's services.

Wayne Bradley has had an outstanding season at his Moosilaukee Inn, Warren, N.H. He had me up there for a few days and I heartily recommend it to any of you fellows and your families looking for a comfortable place to go next summer. . . . **Archie Morrison** is having a long recuperation at East Village Nursing Home, Emerson St., Lexington, Mass. Why not drop him a cheering and encouraging note? We, around here, see him regularly. . . . On a business trip to Buffalo and Montreal, **Alton** (the WOOF) **Cook** stopped in Buffalo to visit Joyce Brado and **George Easter.** Joyce is doing a capital job for us as Class Agent.

Evelyn and **Sam Berke** announce the marriage of their daughter, Jean Louisa, to William Hugh Zietz on October 4 in Lakeville, Conn. Our congratulations and best wishes to this young couple.

In October, **Larry Quirk** left on his annual winter trip to the West Coast. He had hoped there would be a Class meeting here in the Fall, as we've had in the past. But since our big 60th last June, we've slowed down. However, you all look for our annual cocktail party and dinner on Alumni Day next June.

George Easter wrote from Buffalo that he is glad to see 1915 doing so well in contributions to the annual Alumni Fund, thanks to Joyce Brado's willing cooperation. He sees her out there occasionally.

Jim Tobey keeps up a remarkable professional career. In August he spent two weeks at Dartmouth College doing some advanced study. Beginning in October he is giving a 15-week course on "Local Colonial History" at Wainwright Center for Development of Human Resources. Good for Jim. Then he takes off for two months to "suffer" at the Gulf Stream Hotel in Lake Worth, Fla. I think this is listed as the Platinum Coast — ah, me!

Charles A. Bidwell died September 15 in St. Petersburg. He had been manager of the Southern Berkshire Power and Electric Co., Great Barrington, Mass.

All the best to my classmates and their families for a happy and healthy holiday season. — **Azel W. Mack,** Secretary, 100 Memorial Dr., Cambridge, Mass. 02141

16

We are especially happy to announce a new honor for **Harold Dodge.** He received this notice from the Royal Statistical Society, London, England: "I have the honour to inform you that, at the Ordinary Meeting held on 25 June, 1975, you were unanimously elected an Honorary Fellow of this Society, and a formal certificate of election is being sent under separate cover." The certificate stated: "The President, Council and Fellows of the Society have unanimously elected for service to Statistics Harold F. Dodge to be an Honorary Fellow." We talked with Harold recently and he and Grace are well. Harold was raking leaves when we called. . . . Had this nice letter from **Rudi Gruber**: "My copy of *Technology Review* just came. I read your wonderful '16 news immediately! Let me express congratulations on the wonderful job you have done! I deeply regret having missed this event, but my birthday is June 3 (84) and I try to celebrate it in Germany, with my younger brother (we were eight — four girls and four boys, now only three left)." . . . **Walt Binger** writes: "The draft of the reunion write-up is very interesting, very well written and will doubtless have a beneficial effect on the 60th." . . . Other favorable comments were received from **Henry Shepard, John Gore, Theron Curtis, Dina Coleman, Ralph Forsyth**'s wife Isabel. . . . Good to hear from **Doug Robertson** who writes: "Thank you for the photograph of the survivors. I am sorry I was not with you, I hope to be next year. I sold my business last year." . . . This bit of news and philosophy from **John Fairfield**: "You are an old meanie! The photo of the June reunion brought on self-recriminations for our non-attendance; and resolve for June 1-3, 1976." . . . A card from **Joel Connolly** and from **Harold Dodge,** who says: "A quiet summer, minor trips (to the N.Y.C. Art Museum, Utica ditto, and a Weston, Vt., jewelry-designer friend). Gladys' arthritic fingers too cramped to do much jewelry work herself. For myself, gardening! I quote the Old Farmer who said you were not healthy unless you had dirt between your toes, and sweat your shirt wet once a day." . . . **Art Shuey** writes: "We have had a quiet year, a month in Mexico at Easter time is all of our travel, though next month we will have three weeks of trout fishing in Marvel and Aspen, Colo. Two months ago we spent several pleasant days with **Vertrees Young** and Sylvia and as usual enjoyed them both. Vertrees has an artificial hip joint but it hasn't made an old man of him. Rocks and the Episcopal Church keep him busy and then he is a leader in P.A.R. which does its best to keep Louisiana politicos reasonably honest."

From **Val Ellicott**: "Thank you for the note about our 60th Reunion. It is fine that you and a few others have spent so much of your time and effort to keep us posted. I will make a real effort to get to our 60th. I am ashamed to say I haven't been to *any* reunion of our class." . . . In a note from **Francis Stern**: "Sorry to hear about **'Stew' Rowlett.** We were together in W.W.I. and he worked for me as Sales Manager for a couple of years. I understand he had been failing for some time." . . . Nice to have this letter from Gypsy and **Cy Guething**: "Feel sure that what you are doing will result in a better turnout for our 60th than would have without your enthusiasm. For our part, I am

cancelling my entry in the Boston marathon next spring and starting to train for the reunion on the Cape. Suggest that **Jap Carr** take a similar action on the Wimbledon and help make it a grand success. Keep breathin' all of you and best wishes." . . . From **Hy Ullian**: "Frieda and I greatly enjoyed receiving the excellent photographs of ourselves and of the class. The members of the class and their wives photograph exceedingly well and look younger every year. You have managed to keep the class united and the fact that the class meets every year (due to your efforts) means that they are closer than those classes that meet every five years. Frieda and I are looking forward to the next." . . . From **Dan Comiskey**: "Thank you for the photo, showing the 'hardy group' at the 59th. I also see a busy man can always take on another project as you 'pinch hit' as secretary; you must still be healthy." . . . **Allen Petee** writes: "Your letter and official year reunion picture are at hand, and I am glad to have been able to identify **Francis Stern** and **George Ousler,** course VI mates. It is good that the class has someone like yourself, able and willing to pinch-hit in Harold's absence. He has been a ne-plus-ultra secretary, a rare bird in my experience, with the selflessness which Dwight Eisenhower is said to have called the most important characteristic of a good general (and secretary too, I guess). I may have seemed like a wandering maverick when it came to M.I.T. reunions, but it was inevitable because the five year reunion cycles of Yale 1911 and M.I.T. 1916 have often had coincidental time abscissas, and the pull of Yale reunions where I knew everyone always had a greater ordinate than the tug of M.I.T. where I more or less buried myself for two absorbing scholastic years. When M.I.T. 50th and Yale 55th occurred, there was enough phase difference to make it possible to hit M.I.T. first and just get under the wire at New Haven. The M.I.T. 50th was of course notable in many ways. Two small items constantly reminded me of it; your two 1916-1966 granite 'markers' which serve nicely for bud vases, and the precedent-setting old glory — red jacket, trotted out for festive occasions here at Highland Farms Retirement Community, our present abode. There is some doubt as to our making the 60th because Mrs. Pettee's mobility is becoming limited."

We regret to report the death of **Mark Aronson.** Mrs. Aronson wrote: "He had always been very proud of being a graduate of Massachusetts Institute of Technology, and of the Class of 1916."

We close on this happy note: **Don Webster** and Mrs. Robert Henderson Smith were married on June 29, 1975 at the Trinity Church in Boston. Don wrote: "Marjorie is a friend of Nell and me of 47 years standing. We are very happy." . . . Again, we look forward to your cards and letters. Keep writing and we hope that we will have the pleasure of shaking your hands at our 60th in June. — **Ralph A. Fletcher,** Acting Secretary, West Chelmsford, Mass. 01863

17

It would be quite impossible to keep track of all our summer travelers, but the activities of some have come to our attention. The **Beadles** and the **Erbs** were off on an Argonaut Cruise touching on Europe. The

From Howard L. Richardson, '31 (right), President of the Alumni Association, the 1975 Bronze Beaver to Stanley C. Dunning, '17, during the Alumni Officers Conference: "He has been an officer of his Class of 1917 for a quarter of a century as Class Agent, Special Gift Chairman, Assistant Secretary, Secretary and President. He has been a Club officer and member and Chairman of Alumni Association committees, including the Executive Committee. In all these activities — and especially in helping to guide the Class of 1917 to its many accomplishments in service to the Institute, he has been a constant, effective and loyal contributor to the advancement of M.I.T."

Hunters went to England and Switzerland. The **Dunnings** visited western Canada, topping the trip off with an excellent dinner in the revolving restaurant atop the Seattle Space Needle, the prospering remnant of the 1962 Fair. The **Ray Stevenses** confined themselves to a quiet summer at Mattapoissett, Mass., on Buzzard's Bay.

The "**AP**" **Sullivans** have moved to Delmont, Penn. about 30 miles east of Pittsburgh. One wonders what has happened to all of the clocks, his hobby. . . . The **Les Fords** entertained the **Dunhams, Ray Stevenses** and **Dunnings** at their museum-like 1715 home at Marion, Mass. Les has done a piece of scrimshaw work that really tops off Marions's basketry.

It had been some time since there was word from **Larry Clayton,** now living in Jacksonville, Fla. He writes, "I read a bit enviously of the doings of the most active group of my classmates, and sadly, of the frustrations of those who have been 'slowed down,' and those who have passed on." For those of you who have our 30th Anniversary Report volume at hand, Larry's military record will be found interesting.

The September Alumni Officers Conference was attended by '17ers **Lunn, Stan Lane, Stevens** and **Dunning.** This yearly meeting is reported elsewhere and is always thought-producing and inspiring. In all due modesty your secretary reports that he was honored by the Association by being presented with the "Bronze Beaver Award" with citation. This is the highest honor the Association can give and is for service to the Association, hence M.I.T. The award was originated in 1955 and up to this year had been awarded 101 times. This honor was entirely unexpected and it also rewards your secretary for the opportunity to know and work with his fine classmates. In 1967 **Al Lunn** received the Beaver for his outstanding services, when at the same time a Bronze Beaver was awarded to the Class of 1917, for its several activities including its record 50th Year Gift. **Ray Stevens** received the Beaver in 1970 for his many services. The Beaver, 3½ inches tall, stands upright on a marble block.

The Class of 1918 again invited us to its dinner reunion on September 21 at the interesting Endicott House. President Emeritus **Stratton** gave a splendid historical M.I.T. talk which was enjoyed by '17ers **Dunhams, Dunnings, Ray Stevenses,** and **Jess Rogers**.

By the time this is read our 58th Reunion at Northfield will have passed into memory. The post card response to the notice, again, was heartening and quite wonderful. There were 89 replies with 28 men and 22 wives anticipating attendance. To have 89 men respond out of our active list of 159 is praiseworthy and indicative of the spirit of 1917. Space does not permit quoting from all the cards, but there will be quotes and name-listing in future notes.

Ken Lane writes, "This may be our swan song; we are selling our place in New Hampshire and plan to become year-round residents at our place in Florida, to keep **Joe Littlefield** company." . . . **Cy Medding** will be in San Antonio at this reunion time but has high hopes for 1977. . . . **Stan Hall** has hopes too. **Win Swain** comments on, "the lower setting of my time clock." . . . **Tubby Strout** had hopes but the doctor held him up. . . . **Enos Curtin** writes, "*The N.Y. Times* says a gent in California entered a track meet there for men over 80 and claims a record of 16'3" — I did better than 20' so I guess I'm still well physically. Will be in Nevada."

The **Howard Melvins** were making another State of Washington tour and visit. . . . **Pezo Moody** from Denver reports that he "is in good shape but the trip would be too much." . . . **Hobart Stebbins** from Bellevue, Wash., says about the same. . . . **Ed Payne** has retired from the National Security Administration. . . . **Charles Miller**'s four daughters have graduated from the Northfield School. . . . **Vi Proctor** and **Betty Hulburd** regretted their inability to attend.

With regret the deaths are recorded of: **F. Stanley Krug** at Cincinnati, October 12, 1972; **Charles L. Coburn** at Los Altos, Calif., on May 24, 1975; **Richard H. Catlett** at Richmond, Va., on June 17, 1975; **Vicente F. Checa** at Lima, Peru, on June 29, 1975; and **Valette S. Church** at Cotuit, Mass., on August 30, 1975. — **Stanley C. Dunning,** Secretary, 6 Jason St., Arlington, Mass. 02174; **Richard O. Loengard,** Assistant Secretary, 21 East 87th St., New York, N.Y. 10028

18

It is easy to start the 1975-1976 class notes with the pleasant memory of a most enjoyable 1918 mini-reunion at Endicott House on September 21. It started with a sherry hour followed by a satisfying luncheon. Former M.I.T. President Jay Stratton gave us an insight on the problems facing our alma mater and the large public foundations. His talk was one of the most poignant it has been our privilege to hear — too bad we cannot send

copies to all of you. A bit of pleasant nostalgia was introduced with a slide show of the participants from the 1919 *Technique*. (We made a "Guess Who" game of it.) All of us noted it one of the most successful of our mini-reunions. The '18ers included Gladys and **Leonard Levine,** Rhoda and **Charlie Tavener,** Jean and **Julie Avery, Pete Strang,** Dorothy Rossman, Eleanor and **John Kilduff, Nat Krass,** Selma and **Max Seltzer,** Elizabeth and **Julie Howe,** Frances and **Pete Harrall,** Mildred and **Chink Watt,** Marie and **George Sackett,** and Dollie and **Eli Berman.** From the class of 1917 welcome guests included Jeanette and Stan Dunning, Jesse Rogers, Edna and Brick Dunham, Kay and Ray Stevens, Al Lunn, and Conchita Lobdell Pearson. We were happy to have with us from 1919 Lida and Ben Bristol, Margaret and Roy Burbank, and from 1920 Amy and Harold Bugbee. Many cards of regret were received from classmates unable to join us.

I include newsworthy excerpts from five letters. From **Jorge Pena-Polo**: "I thought I might have a chance to see you during our mini-reunion yesterday. Unfortunately I could not make it. It is always so nice to see our dear classmates, and talk to you about our societal problems, or whatever comes to our minds. I'll go back to Columbia, South America, within a couple of months. I wish I could stay longer but hate to be idle and I do not see much for me to do here. So, much to my regret, I have to part." . . . From **William C. Foster**: "Unfortunately, I cannot attend the sixth mini-reunion. I do appreciate your keeping me advised and I wish you and those that attend a successful meeting. For about a year I have been somewhat limited in my mobility since I had so-called heart failure in August of 1974, followed by the implanting of a pacemaker, which appears to be doing a fine job. We were at the shore for two months and the combination of the good pure sea air, good clean ocean water followed by good liquor has made me feel almost 100 per cent once more." . . . From **Sumner Wiley**: "Sorry to have delayed so long. Thanks for your letter and the subsequent note about the mini-reunion on September 21. We shall miss seeing all of you again but it seems better for us not to attempt the trip this time. We are still here at our farm in Casco Bay. We can't possibly eat or freeze all of the nice things coming from our graden at this point so our neighbors share our harvest. Both Winifred and I have had short visits at the hospital since we saw you last but we really are pretty well for the bracket we are in. Greetings to you and all at the Reunion."

From Jean and Malcolm Baber: "I am sorry to advise that we shall not make the mini-reunion this year. We leave early in October for Hilton Head and will probably not return until early in November. Sorry to miss it and my regards to all. There is little to offer in the way of news. We had a quiet summer at home but a pleasant one. Philadelphia is in the throes of getting ready for the Bicentennial. If all the expected visitors do arrive I can't imagine where we will put them, or how they can all see the historic sights. Betsy Ross' house is tiny — Independence Hall not much bigger — Christ Church may not be open — etc. However there will still be plenty to see. If you or the Kilduffs or the Howes do come to Philadelphia, let us know and if we are home we will try to make your stay pleasant." . . . Marion and **Herb McNary** were unable to attend because of conflicting engagements: "The girl next door — born there and very close to us — will be getting married. She has been engaged to a South American doctor, resident at McGill, Montreal, and there were some baptismal records complications that made matters a bit uncertain. As a result it will be a wedding to which Marion and I and two of my daughters will be the only invitees outside of the family.

"Also the stationery I am using (Boston Board of Fire Underwriters) represents a complicated situation dealing with one of its reorganizations over the 112 years of existence. It is one that I have encouraged and will permit me to function as a consultant and legislative agent along with other interests that at this stage in life are more attractive."

Moss Gilbert writes: "After spending the summer in Dedham, my wife and I leave for the winter on September 15; our Dedham home is rented as of that date. Sorry we can't come." . . . Faithful **John Abrams** finally settled his legal case covering water rights out of court and sent a postcard. "Finally I'm getting tranquility in these mountains (Montana — the Big Sky Country) after all the turmoil back in the Sierras."

I regret to record the death of **Marion L. Cousens** on May 29, 1975. In addition, the enclosed note from Elizabeth Sattels tells of the passing of her husband. We extend our sympathy to her. "I am saddened to inform you that my husband, **J. Tillou Sattels,** died on May 31, 1975. He was a victim of cancer and had been ill since August of '74. True to form, he was mentally alert and courageous till the very end. He was always proud of his association with M.I.T." — **Max Seltzer,** Secretary, 60 Longwood Ave., Brookline, Mass. 02146

19

Don Way wrote that he and Barbara vacationed at Newfound Lake near Bristol, N.H., and had a good summer. Their second son Christopher and wife have moved to San Francisco so the Ways are planning a trip there in December or January. He enclosed a *N.Y. Times* clipping of August 28 concerning the death of our classmate **Alexis R. Wiren:**

"Alexis R. Wiren, special assistant to the President of Dowling College in Oakdale, L.I., died in his home there at the age of 78 on Tuesday, December 24, 1974. He is survived by his widow Escha, son John, 2 daughters Marisa and Judith, brother George, and seven grandchildren and two great grandchildren. In 1963 Alexis retired from the Equitable Life Assurance Society as director of development, later director of financial aid and iiaison officer for government grants. He founded the Russian student fund which later became the United Student Aid Fund. He wrote two books — *Practical Management Research* and *A Supervisory Program for the Office*."

Howard H. McClintic, Jr. lives in Delray Beach and plays golf with Fritz Clement, '23, and Dan Groves. We all note that Howard says he did not pay the required fee to get his degree from Harvard added to his degree from M.I.T.

Your secretary had a pleasant and interesting two months at Chautauqua, N.Y. during their busy season, then two weeks in Maine, one week in the New York City area, and two weeks around Washington D.C. before boarding the AutoTrain back to Florida. Enroute from Chautauqua to Maine we stopped and visited **Nelson Bond** in Schenectady, N.Y. who was recovering from an operation on his colon. He is doing well at present and is expected back in Florida early next year. — **E. R. Smoley,** Secretary, 50 East Rd., Delray Beach, Florida 33444

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A welcome letter from **Art Merriman** contains news of his and Mayhew's improved health, very good news, indeed, and mentions a phone visit with **Carleton Alexander** in nearby Wickliffe, Ohio. Art asked to be remembered to Marjorie and **Henry Hills** and says that they reported favorably on the 55th.

Also from Ohio comes news of the death of **Arthur Roberts** of 212 N. Main St., Chagrin Falls, on July 18. Arthur was formerly a resident of New Jersey, living in Ridgewood before moving to Ohio. He was chief engineer for the Colonnade Co. of Cleveland and a member of the International Society of Food Service Consultants, also the Cleveland Engineering Society. He was a Navy Veteran of World War I, is survived by a daughter and seven grandchildren. He was predeceased by his wife and a son.

Another popular and beloved classmate, **James W. Gibson,** died in Brooksville, Maine, on August 4 after a prolonged illness. Since his retirement he had made Brooksville his home but traveled widely during the winter months. He spent last winter in Golden Gate Park in Sarasota, Fla. For many years Jim was an executive and real estate expert with John Hancock in Boston. He was commodore of the local yacht club in Brooksville. He leaves his wife, Lucy, and two sons and a daughter. His genial presence will be sorely missed by us all.

I had a phone call from **Frank Maconi** to tell me that his letter to **Tsen Wei** addressed to Taiwan Trading Corp. had been returned with the advice that Tsen had left their employ and was now in San Francisco. If Tsen reads these notes or anyone else in the class knows his address Mac and I would be pleased to hear about it.

In September, Amy and I were honored by an invitation to attend the Class of '18s mini-reunion which was held at M.I.T.'s magnificent Endicott House in Dedham. Gathered for luncheon were many old friends, members of '17, '18, and '19 and their wives. Slides depicting classmates in their undergraduate days with their three-inch high, stiff collars, no doubt reproduced from *Technique*, were shown, and there was an amusing guessing contest for identification. This due to the enterprise of the redoubtable secretary of '18, Max Seltzer. Finally, our distinguished President Emeritus, Jay Stratton gave a talk on the Institute's early days across the river and its subsequent vast changes and expansion, all in his inimitable and eloquent fashion. A thoroughly delightful occasion and one to keep in mind for another year as the prospects for including '20 in this annual reunion are bright. Your secretary must admit that one aspect of the event that was pleasurable was the fact that he was among the youngest of those present.

Our class has been honored by the establishment of the **Carl Richard Soderberg** Professorship in Power Engineering. Our distinguished classmate served for 22 years on the M.I.T. faculty and established himself as a prime mover in engineering education. Grants for the new professorship have been made by United Technologies Corp. of Hartford and A.S.E.A.-Stel-Laval of Sweden. According to Chancellor Paul Gray, Dr. Soderberg gained international recognition for his pioneering work in the design and development of turbine engines. Head of the Department of Mechanical Engineering and Dean of the School of Engineering before his retirement, he is credited with building and leading one of the world's foremost mechanical engineering departments. The class salutes you, Dick! — **Harold Bugbee,** 21 Everell Rd., Winchester, Mass. 01890

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With a deep feeling of personal loss I report the death on August 21, 1975, of **Joseph Wenick** of Caldwell, N.J. The Class was represented at the funeral service by Class President **Irving D. Jakobson,** Secretary-Treasurer Emeritus **Carole A. Clarke** and his wife Maxine, and your Secretary. Joe served as the long-time treasurer of the M.I.T. Club of Northern New Jersey and ex-officio on its membership, finance, and program committees. For many years he was an Educational Counselor for M.I.T., and he also worked on the Mid-Century and Second Century Fund drives. In recognition of his devoted service to the M.I.T. Club and to M.I.T., he was a first recipient in 1963 of the club's "Outstanding Alumnus Award;" a year later he was given the Bronze Beaver, the Alumni Association's highest award. In his business career Joe worked for Lightolier, Inc., Jersey City, from which he retired in 1963 as Chief Manufacturing Engineer. He worked as a consulting engineer in subsequent years. Joe was active in civic and educational fields both in Jersey City and Caldwell. The Jersey City Chamber of Commerce elected him a "Blue Ribbon Citizen" in 1964. He was a past President of the Caldwell Library Board and worked on many other town committees. The class extends its deep sympathy to his wife Dorothy and their sons, Martin and Richard.

Irving Jakobson reported that the following attendend the Alumni Officers' Conference on September 12-13: **George Chutter, Ed Dubé,** Win and **Royal Wood,** Graciela and **Heller Rodriquez,** Emma and **Al Lloyd,** and himself. Said Jake, "We had a real nice time together — sort of a mini-reunion."

Helen and **Bob Miller** joined Betty and me for lunch early in September on their way back to Cape Cod for a month at their shore cottage. We learned that the Rodriguezes had lunched with them a few days before in Washington en route to Cambridge and after that a visit with **Helen St. Laurent** at Vinalhaven, Maine. A brief note from Helen informed me that Theona and **Al Genaske** of Fryeburg, Maine, were also visitors at Vinalhaven this summer. Amusingly, Helen wrote, "I have a pet gull that checks around the grounds and sits on the roof several times a day. Raymond always called his pet gull 'George' so do I."

Elmer Campbell of Seminole, Fla., described a trip north by car this past summer: the Auto-Train to Virginia ("a rough trip of 16 hours — no berths available so we had to perch on our spines until they were sore, then sway down the aisles to the club car for refreshments and back to the roost for more of the same!"), a meeting of the 50 Plus Club at Colby College, and a reunion in Vassalboro, Maine, with three daughters and their families — a total of 21 for dinner."

Captain **Elliott Roberts** of Westmoreland Hills, Md., responded to my plea for class news in the July column: "After retirement in 1962 after 42 years as an officer of the former Coast and Geodetic Survey, I wrote three published books on science subjects for juveniles in the general field of geophysics. Still gets me royalties. I had previously written more than 100 published articles and for 12 years functioned as editor of *The Explorers Journal*. . . . I acted for 13 years as program director of the Cosmos Club in Washington, staging weekly lectures from October to May, receiving therefore the club's Citation for Distinguished Service. I left that post after reaching a stage of utter exhaustion. **Dick Smith** also is a member and my wife Becky and I see the Smiths frequently. We live a quiet life attending symphonies, ballets, and operas as often as the budget permits." Other classmates please take note and emulate his good letter.

Assistant Secretary **Josh Crosby** wrote from Washington in late September, "On the way north to Maine this summer we spent two days with the **Whittier Spauldings** in Boothbay Harbor. We had an enjoyable ride around the bay in their boat with a picnic on one of the islands." By now the Crosbys are back home in Sarasota.

A note from Mrs. **Robert Felsenthal** tells of a gift to M.I.T. from her son Peter Felsenthal, '54, in memory of his father. The gift was a sailboat to add to the M.I.T. fleet. Your secretary would like to make a date with Peter to take a sail on the Charles river in that boat. Mrs. Felsenthal plans to spend some time in Sarasota this winter with Millie and **Herb Kaufmann** as near neighbors.

A couple of recent letters from **Ralph Shaw** transmitted a "dossier" of interesting happenings in his life since graduation and reminisced about a few of his friends. Rufe has obtained 27 patents during his life, including a "method for welding unweldable steel." He also worked on a development known as "fog vision" using infrared light to see through fog. One discussion with **John Barriger** at our 30th Reunion was about putting trucks on railroads; it is now known as "piggy-backing" and used all over the country. Says Rufe, "I'm having the time of my life making machines that do the impossible and are supposed to be physically impossible to operate." Rufe tells about hearing occasionally from **Harold Cake** in King City, Ore., who reported a recent transcontinental round trip by motor camper to the east coast (Halifax) and back via Canada.

The Jersey Coast clipping bureau is continuing to function satisfactorily: **Cac Clarke** was re-elected President of the Union Landing Historical Society and is continuing to be very active as Co-Chairman of the Brielle Bicentennial Committee. In a joint effort these two groups built a float for the Battle of Monmouth parade in Freehold. Maxine Clarke had a solo show of paintings in May at Point Pleasant Beach.

Your secretaries wish you all the joys of the holiday season and a happy and healthy new year. — **Sumner Hayward,** Secretary, 224 Richards Rd., Ridgewood, N.J. 07450; **Josiah D. Crosby,** Assistant Secretary for Florida, 3310 Sheffield Cir., Sarasota, Fla. 33580; **Samuel E. Lunden,** Assistant Secretary for Calif., Lunden and Johnson, 453 South Spring St., Los Angeles, Calif. 90013

22

Our '22 Christmas greetings include happy and healthful holidays to you all. Your Secretary will be slipping and sliding down to Florida in January and hopes to pick up much good news on the way. . . . **Wallace B. K. Dove** of Providence writes that he is enjoying good health and is active in the school department daily. He is working on the Adult Education Program. Wallace has had a very interesting life in shipyards and auto production and is not planning to slow down. . . . Continuing our last report on the **Dale Spoors,** they have written about the difficulty of housing in Fairbanks, Alaska, and their good visit with Catherine and **Mac McCurdy** in Seattle. They were sorry to miss **Tommy Thomson** in Corona del Mar as they drove down to San Diego.

We have received notes from **Don Carpenter** telling of his visit with Sally and **Thomas W. Alder** of Wilmette, Ill. and **Fearing Pratt** of Hingham, Mass. They all report a pleasant summer in the Martha's Vineyard area. . . . **Norman Joy Greene** of Newtown Square, Pa., has sent a giant picture of the Spalding Inn Club in the White Mountains. It looks like an ideal spot for summer or winter sports — or a Class Reunion. Norman reports that the I.R.S. still loves him. . . . **Raymond E. Miskelly** of Yarmouth Port, Mass., writes that he is counting on the June, 1977 get together. They have been staying close to Cape Cod, but hope to make trips to Florida and southern ports when other obligations permit.

We extend the sympathy of our Class to the family of **Eaton H. Perkins** of Melrose, Mass., who had retired from the Deering Lumber Co. He was a senior member and past president of the Melrose Rotary Club, Director and Vice President of the Melrose Trust Co. and Trustee of the Charlestown Savings Bank. . . . Our sympathy also to Madeline Smith upon the loss of her husband **Irwin J. Smith, Jr.,** retired President of the Surpass Chemical Co. of Albany. Irwin was past President of the American Association of Textiles Chemists and Colorists and a Mason. . . . We are sorry to hear of the death of **C. Harold Whittum** of Rock Hall, Md. Harold was a retired claims manager for the Mutual Liberty Life Insurance Co. and resided in Wayne, Penn., until he retired in 1964. He was active in the Boy Scouts and Masons. He is survived by his wife, Margaret, and two sons. . . . **C. George Dandrow** of Jaffrey, N.H., and Bronxville, N.Y., has written about our loss of **William D. Pinkham.** Bill's wife, Mary, wrote from Granbury, Tex., with their two sons, Bill, Jr. and Peter. We all remember their arrangements for our Pine Orchard Reunions. George has written of Bill as a "rugged son of Maine, a Lincolnesque figure cramped into a cockpit as an airman in World War I." George and Bill tossed the discus and hammer at M.I.T. many years ago. . . . We are sorry to report the death of **Ed. A. Ash** who had been hospitalized for ten months in

Homestead, Fla. Ed has always been a loyal and helpful member of our class.

As you may see, our notes are not the happiest these days. We have very few changes of address so the Class has apparently settled down in retirement to take advantage of the good health that still is with us. A wonderful winter season to you all. — **Whitworth Ferguson,** Secretary, 333 Ellicott St., Buffalo, N.Y. 14203; **Oscar Horovitz,** Assistant Secretary, 3001 South Course Dr., Pompano Beach, Fla. 33060

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Chaplin Tyler writes: "Spent a day recently with Don Carpenter, '22 — always a stimulating experience as Don doesn't bore people with comments on the weather and the latest arthritic sneak attack." **William Daggett Norwood** has published this year his most authoritative book, *Health Protection of Radiation Workers*. After receiving his B.S. and M.S. degrees with our class he went into medicine, receiving his M.D. degree from McGill University in 1935. After engaging in industrial medicine with DuPont he became associated with the operation and health hazards of atomic plants at Oak Ridge and the Hanford Plants. He is now Consultant in Environmental Health at Hanford Environmental Health Foundation, Richland, Wash.

Sadly we report the death of **J. Lindsay Muir** of New Britain, Conn. on July 3. Muir graduated with us in 1923 with a B.S. degree in chemical engineering and was associated for many years in sales work for the Stanley Chemical Coating Corp. of Rocky Hill, Conn. This firm later became known as the Midland Division of Windsor Locks, Conn. He is survived by his wife, Eurith Wachter Muir. . . . With sincere regret we report the passing of **Uncas A. Whitaker** of Harrisburg, Penn. Uncas is probably best known to us as one of the greatest benefactors of M.I.T. with his long history of generous donations, not the least the Life Sciences Building that bears his name. The last we saw of Uncas was at the 25th Reunion of our class, which he attended. We reported many of Uncas' accomplishments previously (*Technology Review*, January 1975). A few further details should be of interest. After earning his B.S. in mechanical engineering with us, he obtained a law degree from Cleveland State University. He also received honorary degrees from Elizabethtown College, Gettysburg College, and in 1974 was honored with the Carnegie-Mellon Alumni Association Distinguished Achievement award. Uncas also received an honorary degree from Carnegie-Mellon, where he obtained a degree in electrical engineering in 1929. In 1941 he founded A.M.P., Inc. of Harrisburg and became its chairman in 1962. Truly we have lost a good friend in the passing of Uncas. — **Thomas E. Rounds,** Secretary-Treasurer, 990A Heritage Village, Southbury, Conn. 06488

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As if the miraculous performance of the Red Sox in the American League playoff had not kept me on my toes, a full page sketch from the *Review* warns me to "Awaken, the December deadline for the Class Notes is October 8." This is emphasized by a person, asleep, walking, candle in hand, topped by a tasseled night cap.

Tid bits of news seemed to have suffered lacuna. The Alumni Officers Conference on September 12 and 13 did bring several of us together — **Herb Stewart, Frank Shaw** and Barbra, **Nat Schooler,** Rene and **Ed Moll, Ray Lehrer, Dick Lassiter, Luis Ferré, Jack Cannon, Gordon Billard** and Velma and **Russ Ambach.**

It appeared to your scribe that the main theme was to find means to increase Alumni participation in M.I.T. intellectual life, perhaps by Association reorganization and direct contact with the academic departments. A Bronze Beaver, the Association's highest individual award, was presented to **Luis Ferré**, a past President and member of many important committees. "As an engineer, industrialist, politician, patron of the arts, philanthropist, his dedication to serving mankind and his belief in the integrity of the individual exemplify the M.I.T. spirit of leadership and service."

Howard L. Richardson, left, awards the 1975 Bronze Beaver to Luis Ferré, '24

Dick Jackson writes that he started flying again. He hopes to fly to Chicago, take a cruise of the Great Lakes by ship, stopping off at Cleveland to visit friends, and then fly from Montreal to Elmira, N.Y., hoping to get in a few more hours in a sailplane." . . . **Phil Blanchard** has been elected Vice President of Engineering and Development of Wyatt, Inc., one of the nation's largest independent fuel oil wholesalers, whose headquarters are in New Haven, Conn. Phil began with the American Locomotive Co., then joined Superheater Co. in N.Y. until 1950, when he became a member of the executive echelon. He is a Director of the Connecticut Petroleum Council and Clean Air Commission. His photograph indicates that he is thriving in a pollution-free environment.

A Fund envelope from **André L. Malherbe** reads, "Besides normal activities, I am now starting on experimental prototypes of deep well pumps, radically different from conventional. Emphasis is on improved efficiency and low manufacturing cost." . . . **Paul Cardinal** and Lorene are planning to leave the comforts of Naples, Fla., on January 21 and sail from Ft. Lauderdale, Fla., via the Royal Viking Star's Cruise. They will heave up and down in the Panama Canal locks to the Pacific and San Francisco, dropping anchor on February 8. During their ten days there, they would be happy to be welcomed by friends. They will fly back to Naples during the week of February 16. Paul and his Florida sun-worshippers are still up in the air re the Fourth Florida Fiesta. Puerto Rico could be the locus. Constructive views are most welcome.

Frank Shaw mentions that he and Barbs spent a week during September in New Hampshire, stopping to see Ed and Rene Moll and going on to Waterville Valley in the ski country. There was no skiing, to Frank's delight, but they did gorge themselves at Tullulah's high class Salle á Manager.

At deadline time I received news of the deaths of two of our classmates: **Eugene Cronin** on August 4, 1975, in Winthrop, Mass.; and **Samuel J. Hatfield** in June, 1975, in Burlington, Vt. Sam at one time was division manager of the New England Fire Insurance Rating Association. The sympathy of the class is extended to their families. — **Russell W. Ambach,** Secretary, 216 St. Paul St., Brookline, Mass. 02146; **Herbert R. Stewart,** Co-secretary, 8 Pilgrim Rd., Waban, Mass. 02168

25

Will Gardiner for the past five years has faithfully kept you informed through this column of the activities of your classmates. He has done a superb job, but now you will have to put up with my efforts once more. At least you have enjoyed a respite.

In past years these notes have reached only a portion of our Class, those giving to the Alumni Fund. Now that we have passed our golden anniversary, I understand that the entire class will receive the *Review*; and it will be most satisfying to be reporting to all members of the Class. Make certain that each and every one of you keeps me informed of your doings so that our notes can be truly newsy.

This set of notes is being prepared many weeks before you will see them. This is in part because the deadline for this issue occurs three days before Evelyn and I return from a trip to the British Isles. We are traveling with a group called the Harwich Wayfarers, a spin-off from the Harwich, Mass., Council on Aging.

During the past several months letters from classmates who attended the 50th have been most complimentary about the job **Jim Howard** and **Ed Kussmaul** did in planning and running the Reunion, and all the praise was well warranted. One of the unique features was the ceremonial tea presented by Hisako and **Kamy Kametani**; Kamy gave a book, *The Tea Ceremony* to the Alumni Association and it is now in the M.I.T. Library.

Our class was well represented at the Alumni Officers' Conference in September by **Will Gardiner, Jim Howard, Ed Kussmaul, Ken Lucas,** Elinor and **Sam Spiker, Courtenay Worthington,** and your secretary. The highlight for the Class was the award of the 1975 Bronze Beaver to **Sam Spiker.** This is the highest award given by the Alumni Association, and Sam has certainly earned it; most of you are well aware of Sam's efforts in behalf of the Alumni Association, the Class of 1925, and M.I.T.

Notes from classmates are always welcome. One delayed in reaching me was from **Robert Read** in Sackville, New

The 1975 Bronze Beaver Award is presented to Samuel R. Spiker, '25 (left), by Howard L. Richardson, '31, President of the M.I.T. Alumni Association, at the Alumni Officers' Conference: "For nearly twenty years he has been active in service to M.I.T. through Class, Club and Alumni Fund activities. He helped to reshape alumni programs in New York, was a key adviser in initiating seminar programs for M.I.T. alumni and was a leader in his Class' 50th Reunion gift program."

Brunswick, indicating he hoped to make the reunion, but unfortunately he did not show. . . . **Harry B. Smith,** now residing in Winthrop, Mass., writes that after a year of retirement from Niagara Mohawk Power Corp. in Syracuse, N.Y. (1967), he found full retirement didn't agree with him; for the past five years he has been working for Charles T. Main in Boston six months of each year. He has been involved in electric power system planning for various clients, and this has resulted in interesting trips to Indonesia and Iran (accompanied by his wife Eleanor). Summers are spent at Winter Harbor, Maine, busy with his sailboat.

Does anyone have a 1925 *Technique* or a 1925 graduation program which he is willing to part with? If you have either or both get in touch with **Virgil (Hal) F. Halliburton** at 712 Park Hill Dr., Drawer L, Nevada, Mo., 64772. Hal and his wife were at the Reunion — their first in 50 years — and it was wonderful to renew their acquaintance.

One of the sad duties of the Class Secretary is to report the passing of classmates. Since the last class notes were prepared there have been three deaths: **Sidney W. Andrews** in Pelham, N.Y., on June 23, 1975; **Edward W. Carlton** in Los Angeles, Calif., on June 25, 1975; and **James F. McIndoe** in Sausalito, Calif., on April 15, 1975. No further information is available regarding these classmates, and if any of you can supply me with additional facts please do so.

The holiday season will be upon us by the time you read these notes so let me extend to all seasons greetings and best wishes for 1976. — **F. Leroy (Doc) Foster,** Secretary, 35 Woodland Way, P.O. Box 331, North Chatham, Mass. 02650

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While our own sailboat "Beaver" has been safely under its winter cover for nearly a month, a few staunch local sailors leave their boats on their moorings for a much longer period. This is fortunate because after writing these notes I have an invitation to go sailing with a friend, going out around the breakwater and Salvages which are outcroppings of rock a couple of miles offshore that are frequented by passing sea birds this time of year. A silent gliding sailboat can often get close before they fly off. It promises to be an interesting afternoon if the breeze calms down from its present 15 to 20 m.p.h.

A nice letter from **Ted Larratt**'s widow gives additional information on his passing, which we reported last month. Ted had been seriously ill with cancer for several months, but as he grew weaker he had a strong desire to come home to New England; so on his birthday, May 25, he was flown by air ambulance from Orlando to Lewiston, Maine, and succumbed on June 7 at his home in South Paris, Maine. Barbara says that Ted had often spoken of coming to Pigeon Cove for a visit and in one of his pockets our name and address was underlined in his handwriting. Ted, as we mentioned last month, spent his entire career in aircraft design with the leading aircraft manufacturers.

Our illustrious gold medal collector, **Stark Draper,** has just added another to his weighty collection. On September 9 he received the Lord Kelvin Gold Medal of the British Institution of Civil Engineers in London. And you should see the new Draper Laboratory that is going up east of Main Street at the rear of M.I.T. This summer the steelwork went up fast, and now the stonework is pretty well fastened to the frame. It is an imposing structure designed by the Skidmore, Owings Group of architects, and it just looks as though it could be finished in time for Stark to give us a tour at reunion time. Stark, we are inviting ourselves!

You should have received a copy of the new supplement to the *Technology Review, MIT76*, a month or six weeks ago. Our Sailing Pavilion program received the banner position — the whole front page. Day after tomorrow we are having a meeting of the sponsoring committee in Cambridge and classmate **Pete Doelger** is coming from Florida to attend. We have passed the halfway mark on our fund raising and have had excellent backing from members of the Class of '26, and of course their contributions all count toward our 50th Class Reunion gift as well.

On September 12 and 13 we attended the biennial Alumni Officers' Conference which I'm sure will be covered elsewhere in the *Review*. However, as always the feature about M.I.T. that is most impressive to me is the ability to change — not with the times but ahead of the times, which in more concise terms is to lead.

. . . We have just returned from the sail I spoke of at the beginning of the notes and it was delightful — we sailed about two miles offshore in my friends' Bullseye. There was considerable chop and a good breeze. On the offshore side of the breakwater there is an area called the flatground because of the contour of the ocean's floor and this is where the ducks gather because of rock outcroppings. My friend was able to spot ducks on the water's surface that my untrained eye could not see until we were in their midst and they were taking off. After a half dozen such forays he suggested that we head back for the harbor before the sun started to drop but neglected to tell me that he was wearing waffle underwear. By the time we moored I was ready in my chinos to dash for the coffee shop at the head of the wharf and absorb a few B.t.u.s of steaming black coffee. It really was a delightful afternoon.

A postcard from **Tony Gabrenas** has just arrived from Lithuania, U.S.S.R., where Tony is visiting relatives who he says are without luxuries but are well-fed and clothed. Also Tony says "So long till 50th," and this is an appropriate time for us to say Cheerio until 1976 and Happy Holidays to all. — **George Warren Smith,** Secretary, P.O. Box 506, Pigeon Cove, Mass. 01966

27

The 50th Anniversary is creeping up on us. By the time you read these notes, there will be barely 1½ years left to reach the goal for the Class Gift.

On September 30, **Bud Fisher** called together the ad hoc steering committee on the 50th Anniversary Gift at the Faculty Club in Cambridge. Those present were Bud, **Dick Hawkins, Joe Burley, Russ Westerhoff, Dike Arnold, Ezra Stevens,** and **Ray Hibbert.** I was tied up with New Rochelle city business at the last minute, and couldn't make it, but I have had reports from both Ray and Bud. Reunion plans are progressing nicely, but the gift drive is lagging. Bud has set his sights on $500,000, but only about $200,000 has come in to date. The past couple of years have not been prosperous for those of us — the great majority — who are now subsisting on Social Security, fixed retirement income, and whatever return is available from the savings we've managed to accumulate over the years.

There is some evidence, nevertheless, that a part of the lag in contributions is due to the psychological effect of asset shrinkage and inflation, rather than actual hardship. The Committee is still hoping that the shrinkage in contributions from those who are actually unable to give more can be made up by increased contributions from some of our more comfortable classmates. And this applies to those who give in three-figure amounts, as well as to the few who can give in four and five figures.

Dike Arnold, chairman of the Reunion Committee, told the group that, in 1977, Graduation will be on Monday, M.I.T. Night at Pops on Thursday, and Alumni Day on Friday. For the period from Monday afternoon to Thursday afternoon, the Committee has engaged the Wianno Country Club on Cape Cod for those 1927 classmates and their wives who want to continue and renew the long friendships most recently confirmed at Bald Peak at the 40th and 45th Reunions.

Ray Hibbert took advantage of the presence of most of the executive committee to fill vacancies created since the last reunion.

The following is the current slate, which will continue in office until the entire class has an opportunity to vote in 1977:

Honorary President	Jim Lyles
President	Ray Hibbert
Vice Presidents	Bud Fisher
	Dick Hawkins
50-Year Gift Chairman	Bud Fisher
Class Estate Sec.	Russ Westerhoff
Class Alumni Fund Sec.	Dick Hawkins
50th Reunion Chairman	Dike Arnold
Class Secretary	Joe Melhado

It's been quite a while since we heard from **Horace Osborne.** He has been leading a busy life since retiring from the General Services Administration. He is active in the International Order of Odd Fellows and a past commander of Flotilla 609 of the U.S. Coast Guard Auxiliary. He recently built a 20-foot cabin cruiser, which he and his wife and family sail out of Brandt Roack, Cape Cod Bay. He reports three children and six grandchildren. . . . This past spring, **George Jenkins** got up at 3 o'clock in the morning to attend the 6:15 A.M. reenactment of the Battle of Lexington, and he also attended the reenactment of the Battle of Bunker Hill in June. . . . **Harold Edgerton** has retired from the Board of E. G. & G. as of April 16, 1975.

Lloyd MacAdam sends me a clipping reporting the death in September of **Paul Eaton,** in Portland, Maine. After graduation from M.I.T. with our class, Paul received a master's degree in education from Harvard. He taught English literature at M.I.T. for some years, and in 1947 became dean of students at California Institute of Technology in Pasadena until his retirement in 1968. He had long been a summer resident of Maine and moved to Kennebunkport on his retirement. He had been a lieutenant commander and engaged in naval operations in both the Atlantic and Pacific in World War II. He had been active in the local church, Historical Society, Museum, and Grange. He is survived by his wife, Katherine Emery Eaton; a son, James E. C. Eaton of Simsbury, Conn.; and a daughter, Rebecca C. Eaton of Cambridge, Mass.

Lloyd MacAdam, by the way, continues well, and works at maintaining his health with regular, strenuous exercise, a low-fat, low-cholesterol diet, and no smoking. He expresses distress that the profession of medicine — to which, incidentally, his daughter belongs — pays so little attention to preventive medicine.

I have word from **Jim Collins'** brother that Jim passed away suddenly on July 31, at Belmont, Mass. Jim had worked as a Manufacturers' Agent, representing a number of producers of electrical and mechanical equipment. He leaves his wife, Esther (McCafferty), five children, and a number of grandchildren.

As these notes are written in October, your secretary is still Acting Director of Finance at New Rochelle and trying — unsuccessfully so far — to help select a permanent Director. Meanwhile, we are working days, evenings, and weekends trying to put together a budget free of any of the mistakes of our big neighboring city to the immediate south of us. — **Joseph H. Melhado,** Secretary, 24 Rodney Rd., Scarsdale, N.Y. 10583

28

We have a most cheerful and enthusiastic letter from **Tom Harvey** inspired, he says, by reading Class Review. A fine picture of Tom and Gracia taken on their 45th wedding anniversary was enclosed, supporting their claim of enjoying good health. Of his travels Tom says: "Gracia and I have just returned from a trip on the steamboat Delta Queen from St. Louis to St. Paul. We have traveled rather widely — all 48 states of the continental U.S., Alaska, Canada, Newfoundland, Mexico, Greece, Turkey, Spain, England, Ireland, and Scotland. But for sheer pleasure the trip on the Mississippi was number one. The food was excellent, our cabin most comfortable, entertainment and music delightful and the scenery beautiful. We chose to go up on the northern end of the river as the levees do not hide the land on this part of the stream. Side trips to Navoo, Prairie du Chien and Winona added to our pleasure. We heartily recommend this trip to any and all of you who wish to see some of America's historic heartland."

The Harveys have lived in Indianapolis since 1941. Daughter Diana was graduated from Butler University and now has one son at Ball State University and a second son still in grade school. Tom's son (also named Thomas) was graduated from Miami University in Oxford, Ohio, spent three years in the Navy, then earned his M.B.A. at Northwestern. He holds the rank of commander in the Naval Reserve. Young Tom has a little daughter and a son only a few months old. In a second letter Tom sent us his recipe for Kitimat Cocktail (we will send it to anyone who asks) and declared that he and Gracia expect to attend the 50th in June, 1978.

A note from **Walter (Dick) Hildick** tells us that he, **Frank Sweeney** and **Nap LaCroix** all went through high school together in Leominster, Mass. However, each was graduated from a different department at the Institute. . . . We are sorry to learn from **Joe Collins** that his brother James ('27) died on July 31. A note was sent expressing sympathy to Joe and to his brother's family. . . . **Gabe Disario** writes: "To simplify things we have moved into an apartment. Now we can more safely lock up, go down to the coast, and stay at the club. Swimming is an all year sport here [Venezuela]. In May we took a three-week trip to mountainous western Venezuela. We hope to resume foreign travel, stopped since the 45th reunion by illness." . . . In his own style **Bill Hurst** writes to deny that he has anything of a superior characteristic in his customary use of calculus. Apparently it is a common part of the language of petroleum engineers.

We are pleased that a number of class widows have kept in touch and, in several cases, have expressed a wish to continue in Class activities. Recent letters have come from Perry (Mrs **Richard D.) Hoak**, Francis (Mrs. **Carl F.) Myers**, and Mary (Mrs. **Arthur A.) Nichols.**

In a letter to **Jim Donovan, Dempe Dempewolff** reported: "I just found a copy of the 1928 Graduation Pictorial. It is faded somewhat but in fair shape with folds. If you are planning to collect memorabilia for the 50th, I'll look for other items including Voo Doo bound volumes should they not be available otherwise." Perhaps other classmates would be willing to look around for items to exhibit. The M.I.T. Historical Collections would be pleased to receive any items that bear upon the Institute's history. We are happy to note that Lillian (Mrs. **Gilbert) Unverzagt** has donated her collection of M.I.T. steins and ashtrays to the cause.

The Class was well represented at the 1975 Alumni Officers' Conference. Attending were Frannie and **Jim Donovan,** Gladys and **Dave Olken,** Anne and **George Palo, Dick Rubin,** Florence and **Walter Smith,** Ruth and **Abe Woolf.**

A number of you have asked if there are any plans for a mini-reunion. We are now midway between major reunions and this is a good time to hold a mini if enough interest is shown. Will all those in favor please write in and say so? One suggestion is that we might gather in Mexico City during the M.I.T. Fiesta in the spring of 1976.

We regret to report that **Richard T. Davidson** died on October 3, 1975. Dick was retired Vice President of Boston Old Colony Insurance Co. and living in Delray Beach, Fla. We are indebted to Frank Kurtz ('22) who thoughtfully wrote and sent an obituary clipping. Frank said that he and Dick played tennis three times a week until about six months ago when Dick underwent surgery for a brain tumor. On behalf of the Class we send our heartfelt sympathy to Dick's wife Elizabeth and to their family. — **Walter J. Smith,** Secretary, 37 Dix St., Winchester, Mass. 01890

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George A. Crandall writes, "Yesterday (August 8) was my 69th birthday, but I have no thoughts of retiring yet. My wife and I took a tour of Russia this spring with a group of retired officers. It was most interesting and very enjoyable. Business in the Rocky Mountains area is especially good and Wyoming Wholesalers, of which I am president, is growing each year. We were in Rhode Island in July for the wedding of one of our grandsons. We hope to make it at our 50th Reunion in 1979."

A note from **Charles Frank, Jr.** reads: "Since my retirement from the Raytheon Co. in July, 1973, there never has been a dull moment. I am on the 'go' all the time. I do volunteer work with the Waltham, Mass., Chapter of the Red Cross, participating in their blood drives two or three times a week. I also sing with the Highland Glee Club of Newton, which recently won first prize in the N.E. Federation of Men's glee clubs contest."

At the Alumni Officers' Conference this fall, **George W. Burgess** was one of the recipients of the coveted 1975 Bronze Beaver award "in Grateful Recognition to Distinguished Service to the Alumni Association." Those who were present at the Conference were: **Russ Clark** (Dallas, Texas), **Bill Bowie** and his wife, Sally, **Bill Baumrucker** and his wife Doris, **Wally Gale, Ellie Horwitz,** and your secretary.

A brief note from **Al Moore** reads, "Thanks for the birthday greeting which was waiting for me upon my return from a recent trip. I seem to keep happy doing many things in a lot of different ways and places. My best regards to all." . . . **Larry Moses** and his wife Kay took an enjoyable two-week cruise on the Italia, visiting ten Caribbean ports in South America and the canal zone. They both are well and living happily after five years of retirement in Sarasota, Fla.

John G. Sullivan writes, "I find retire-

From Howard L. Richardson, '31 (left), President of the Alumni Association, the 1975 Bronze Beaver to George W. Burgess, '29, during the M.I.T. Regional Conference in San Francisco on September 25: "A dedicated and loyal alumnus of the Institute, his volunteer activities are characterized by the thoughtfullness, thoroughness, and integrity fundamental to successful undertakings. His participation and support are central to all major Institute endeavors in the San Francisco Bay area."

ment every bit as exciting as when I was back in the business world, and lots more fun. I have also found, as some of our classmates have too, that there is not enough time to do all the things we had planned to do. Having found that there is little hope of improving my golf game, I have been putting some time on the Government Study Committee of our town of Dennis, Mass., exploring different ways to improve the town operations. We spent several weeks last winter down south, but we were truly glad to come back home to Cape Cod, a great place to live. Best wishes to all." . . . **Bill Baumrucker,** president of our class and senior vice president of Charles T. Main Co., has no thoughts of retiring. In recent years, he has been globe-trotting in conjunction with his work, combining business with pleasure. Last spring Olive and **John Rich** joined the Baumruckers and visited Norway, Finland, Russia, Afganistan, Iran and Spain. They hired a car and toured around the countryside, which, in Bill's opinion, is the best way to see a country.

Edward B. Papenfus writes: "I am enjoying my retirement years very much. My wife and I do a little traveling and we recently visited South Africa, the land of our birthplace. We were very much impressed with the social and economic changes that have taken place particularly in the field of race relations. It was so good to mingle with the people again who believe in free enterprise, unlike the oppressive socialism of British Columbia."

Two of our classmates have passed away, according to news received from their widows. The widow of **Wilmer L. Barrow** wrote to announce the death of her husband on August 29, 1975, and enclosed an obituary from the *Boston Herald Advertiser*. Dr. Barrow retired in 1970 as vice president of research and development engineering of Sperry Gyroscope, Division of Sperry Rand Corp. He received his B.S. degree in engineering at Louisiana State University in 1926, M.S. degree in electrical communications at M.I.T. in 1929, and a doctorate in physics from Technische Hochshute, Munich, Germany in 1931. He served 12 years on the M.I.T. faculty, being one of the original members of the radiation laboratory. He was chosen to establish and direct the Institute's Radar School. During W.W. II, he served in the armed forces in a number of advisory capacities and received presidential citations. During his distinguished career, he was presented several top professional awards for his work and he was listed in *Who's Who in Electronics*.

The widow of **Thomas V. Moore** writes, "My husband died of a heart attack on August 19, 1975, aboard his beloved 43-foot boat *Missy*. He was 67 years old and had been retired from EXXON since 1962. He received his B.S. degree from Rice University in Houston and his master's from M.I.T. in 1929. He worked for the Humble Oil Co. from 1925 to 1942, was on the Manhattan Project in 1942-43, and was connected with the M.I.T. Chemical Warfare from 1943 to 1945. He was affiliated with the Standard Oil Co. of N.J. from 1945 to 1960 and on loan to the Institut Francais du Petrol from 1960 to 1962."

Frederic D. Merrill is enjoying his retirement and doing a little traveling with his wife Carmen. They recently completed a tour of Cape Breton Island (Nova Scotia). Fred is planning to take a course under Fairleigh Dickinson's "Older Persons Programs." . . . **William M. Harris** writes, "After building one of the first innovative contemporary houses in Greenwich, Conn., and living in it for 38 years, we have finally sold it and moved to Bay Indies in Venice, Fla. I have created a super workshop for myself to pursue my life-long ambition of photography. I really enjoy this new way of life. After one year and a summer session at M.I.T. in 1929, I attended Boston University, College of Business Administration, and received a degree of B.B.A. cum laude in 1930. The basic engineer's way of thinking — 'getting all your ducks in a row before popping off half-cocked' — has been a useful approach to life. My specialty, before retirement, was industrial design, advertising, and sales promotion." . . . **J. Wesley Walters** writes: "We spiced up our annual trip to Arizona this past March by traveling via Yellowstone National Park for a winter view of its wonders. Our oldest granddaughter, Connie, who helped entertain the gang at our 35th class reunion by doing the 'Twist,' has finished her second year of teaching and is now looking forward to her marriage in November."

Harold C. Pease writes: "I retired on May 1 after 32 years as an engineer for the Factory Mutual. Since then, I have spent a month in Florida, two weeks in Spain, and a several days in short trips to the Jersey shores. I have also gone to Massachusetts several times to see my son, his wife, and my two grandsons. My future plans are indefinite, but I may take a trip to England this fall. Since I have had it with ice and snow, I'll probably spend the winter in Florida."

Winfield H. Bearce writes: "We retain a small home in Augusta (Maine) and a cottage at Pemaquid Point on the ocean. We plan to return to Naples, Fla., in November and stay there until middle of April. Three places seem to be too many, but we don't seem to be ready to give up any of them yet. We are glad to avoid the Maine winters, but it is home just the same. Would like to see any '29ers who are in the neighborhood. Sorry to have missed the 45th Reunion, but still hope to get to M.I.T. one of the coming Class Days and perhaps the 50th Reunion." — **Karnig S. Dinjian,** Secretary, 6 Plaice Cove, Hampton, N.H. 03842

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As usual, the Alumni Officers' Conference in mid-September provided a stimulating exposure to many exciting things currently happening at M.I.T. One of the most interesting sessions was the program arranged for members of the Educational Council: three panels of students — each panel including at least one woman and one black — whose majors were management, science, and engineering. The poise and intelligence with which these young people fielded some rather difficult questions was most impressive. To the best of my knowledge, no other members of the class attended any of the Conference sessions.

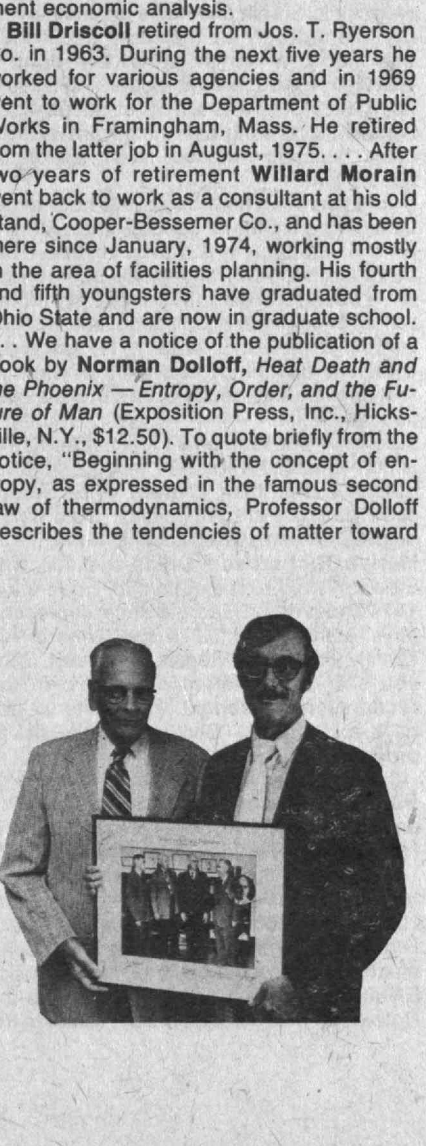
Tony Savina retired as of February 1, 1974, after a little more than 29 years at the Stamford Research Laboratories of American Cyanamide Co. He has since been doing a little part-time work as a consultant in two areas — the preparation of technical sales bulletins and quality evaluation of natural water-soluble polymers. Julia is continuing to teach in the Stamford public schools. Tony was unable to attend the Reunion because of a conflict with his younger daughter Jean's graduation from Gettysburg College. Tony reports that the greatest impact of retirement has been "to reduce my income and eliminate my holidays and vacation." . . . **Vincent Thormin** has retired and is living in Kingsbury, Quebec. He lists as extra-curricular activities art and part-time preaching. The Thormins have four children including an artist, an ornithologist, and a kindergarten specialist. . . . **Clyde Tirrell** retired as of

June 28, 1974, from the Naval Electronics Laboratory Center in San Diego, Calif. His field was radio communication problems with emphasis on shipboard antennas. He was active in the local section of Institute of Radio Engineers. . . . **King Tow**, formerly a civil engineer for the El Dorado County Public Works Department in Placerville, Calif., retired in 1972. The Tows have five children including a registered nurse, a Bell Telephone Labs staff engineer in Holmdel, N.J., a staff engineer at General Atomic Co. in San Diego, an Assistant Professor of Physics at Brown University, and a social counselor in the San Francisco unified schools. King says that he would like classmates to write to him at 3829 Radcliffe Lane, San Diego.

Sol Uman writes that he is slowing down his business activities which were in the commercial, industrial, and residential construction field. He and his wife spend part of each winter in Florida and Palm Springs, Calif. The Umans have three children: Henry, M.I.T., '57, who is a partner in the law firm of Kaye, Scholer, Fierman, Hays and Handler; Stephen, who is regional manager of a large investment and construction firm in Florida; and Pat, who is married to an eminent cardiologist. . . . **St. George Arnold** has received the distinguished alumnus award from Randolph-Macon College in Ashland, Va., from which he graduated in 1926 prior to his years at M.I.T. My records indicate that he does or did work as a consultant to the Oak Ridge Operations of the U.S. Atomic Energy Commission in the field of power procurement economic analysis.

Bill Driscoll retired from Jos. T. Ryerson Co. in 1963. During the next five years he worked for various agencies and in 1969 went to work for the Department of Public Works in Framingham, Mass. He retired from the latter job in August, 1975. . . . After two years of retirement **Willard Morain** went back to work as a consultant at his old stand, Cooper-Bessemer Co., and has been there since January, 1974, working mostly in the area of facilities planning. His fourth and fifth youngsters have graduated from Ohio State and are now in graduate school. . . . We have a notice of the publication of a book by **Norman Dolloff**, *Heat Death and the Phoenix — Entropy, Order, and the Future of Man* (Exposition Press, Inc., Hicksville, N.Y., $12.50). To quote briefly from the notice, "Beginning with the concept of entropy, as expressed in the famous second law of thermodynamics, Professor Dolloff describes the tendencies of matter toward disorder and toward order, with the accompanying changes in energy relationships that entropy represents. He depicts these, respectively, as 'heat death,' or Warmestod, and as negentropy, or — in his own term — ordiny. These may be taken as the Phoenix of order rising, like the mythical bird, from the ashes of a tendency toward the universal unavailability of energy." As many of you know, Norm has been on the staff at San Jose State College for many years and at one time was Chairman of the Geology Department. He and Phyllis live in Saratoga, Calif., high on a hill with a picture window providing a spectacular view of the valley below.

John Pratt died on August 24, 1975. According to my records, John had continuing health problems since he sustained a cerebral-vascular accident in 1969. However, as recently as 1974, he was maintaining an active schedule as G.O.P. Town Committee Chairman in Castine, Me., where he lived, as well as County Finance Chairman, Town Tax Collector, and Chairman of the Zoning Board of Appeals. He also operated Pratt's Photo Service and was active in a Y.M.C.A. childrens' swim program as well as singing in his church choir. — **Gordon K. Lister,** Secretary, 530 Fifth Ave., New York, N.Y. 10036



Charles Norris, '31 (left), Dean Emeritus of the College of Engineering at the University of Washington, and Dean W. Ryland Hill pose with a photo of the five previous deans. The College is in the process of selecting a new Dean.

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Congratulations to **Ken Germeshausen** on his 1975 Bronze Beaver award which reads as follows: "With ties to M.I.T. which span many decades and many avenues, he has become one of the most effective, astute and informed advisers to the Alumni Association and the Institute. As a member of two Visiting Committees, the Corporation Development Committee and the Council for the Arts, and as Vice President of the Alumni Association, his counsel and his extensive and thoughtful contribution of time and energy have been an inspiration to the staff and to his colleagues in furthering the goals of the Institute." The presentation was made by our prexy, **Howard Richardson,** who has recently been elected to President of the Alumni Association. . . . A note from the M.I.T. Alumni Fund has advised us that **Ken Jamieson**'s mail should be directed to Suite 4601, 11 Milam, Houston, Tex. 77002; phone after Dec. 1 — 713-656-6694. Although he is retired, Ken will remain a director of Exxon. . . . Speaking of retirement, I retired officially at the end of August and find that I am busier than ever doing many of the things I've wanted to do for some time but didn't have time for. In addition, Sally has kept me busy helping her with jelly making and canning. I enjoyed seeing Howard and Evelyn Richardson, and **John Swanton** and Louise at the Class Officers' meeting in September. Howard did a splendid job in his new position as president of the Alumni Association and John Swanton has contributed greatly to your Class Notes. Hope you all have a Merry Christmas and a wonderful 1976. — **Edwin S. Worden,** Secretary, 35 Minute Man Hill, Westport, Conn. 06880; **Ben W. Steverman,** Assistant Secretary, 260 Morrison Dr., Pittsburgh, Penn. 15216; **John R. Swanton,** Assistant Secretary, 27 George St., Newton, Mass. 02158

Howard L. Richardson (left) presents the 1975 Bronze Beaver Award to Ken Germeshausen, '31

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Lawrence F. Wagner was the recent recipient of the coveted "Engineer of the Year Award" from the trustees of the New Jersey Society of Professional Engineers at the Sheraton Deauville Hotel in Atlantic City. Lawrence retired as county engineer of Ocean County in 1972 but remains very active in his hobbies of world traveling, photography, piano, boating, and geology. He is a navigator in the Barnegat Bay Power Squadron. . . . **G. Edward Nealand** was elected to life membership in the Purchasing Management Association of Boston, for many years of service to that organization.

Your Secretary extends best wishes for a happy holiday season and a very healthy and prosperous New Year. — **John W. Flatley,** Secretary, 6652- 32nd Street N.W., Washington, D.C. 20015

33

Dick Morse gets top billing, as he has two notices. Dick is head of the M.I.T. Development Foundation, a venture-capital project at Cambridge. The idea is to get new ventures off to a good start by finding the money that is needed. This is quite new in educational institutions, though not so much as in private industry. Apparently, it is an effort on our part to take an active part in encouraging others to follow Dick's leadership, and to expand the correlation between the inventor, and the means to finance his venture. Another mention of Dick's activity comes

from Scientific Energy Systems Corp., a firm of which Dick is now Board Chairman. It appears that S.E.S. is manned to a large extent by M.I.T. people. Dick, we observe, is more than a busy man. He is more like two. We have every right to be proud of our classmate, who brings to the class a lot of distinction.

Jack Lane, hasn't been heard from before, but known, nevertheless. Jack, a long-time lubricating man, is a Director of the National Lubricating Grease Institute. As a Director, he represents the Compagnie Francaise de Raffinage, Paris. It appears that Jack was Mobil's representative on the N.L.G.I. Board, but has resigned. Hence, to remain on the I.L.G.I. Board, he must be there as representative of the above French concern. I do not follow Jack's story too well. It is possible that Jack will drop us a line, and clarify his status for us. . . . **Ivan Getting** received the Pioneer Award of the I.E.E.E., Aerospace and Electronics Systems Society. Our best, Ivan. (Why not drop us a line, personal like?) . . . Every once in a while, **Warren Webster** comes up for air, and drops me a line. This time Warren, via the Fund Capsule, says that he is playing a lot of golf (written in May), and is keeping fit. He also says that he is keeping in touch with the younger generation, in an "attempt to counsel them." . . . From **Donald H. Newhall,** comes another fund capsule, quite complete: "Founder of, and active President of, Harwood Engineering Corp. of Walpole, Mass. The firm is internationally known in high pressure, and, high temperature technology, as specialists." Don is a Fellow of the British Institute of Mechanical Engineers, Member of Sigma XI, and has three grandchildren, which is all very fine, except that many have more, like **Maurice Brashears.** Well, Don, I can't brag either, as I have only four. . . . **Richard B. (Dick) Smith** is another retiree, and, with his "Wonderful wife, Eileen" he is keeping his good health, spent last winter in Florida (where?) and then expected to spend most of the summer fishing in northern Minnesota. Dick, I spend the winter in Florida, too (see address at bottom).

This one appears to be doomed to be just quite a bit shorter than we had hoped: There is very little material available at this time. Inasmuch as it is two months since the Interim letter was posted, perhaps those who have not signed up for the Mini Reunion, Mex. Fiesta, ought to get busy and do so. Write to **Bill Bauer,** right away. We just can't let that other class beat us out, with the head start we had. We expect a majority of our class officers to attend, and enough new attendees to get a start on a classful of Eager Beavers. As you know, **Dayton Clewell,** 1933 President, has every intention of taking in the Fiesta, even though he is still very active as Senior Vice President of Mobiloil, and very much subject to first allegiance to Oil.

I have a short note from Executive Vice President, **Ellis Littmann,** who asks why, after signing up for the September Alumni Officers Conference, I was not seen. 1933 was represented by Ellis, **John Wiley,** and **Westy Westaway,** and yours truly, because I did attend, but not all of it. I had to miss the Friday evening activities but I got up at 5:00 A.M. Saturday, drove to Cambridge, and had breakfast with the *Review* staff. After that I took in the morning group session, and then off to N.H. where my good wife, Leona, was alone that day. Beyond this, as I reminded Ellis, I get around a lot, perhaps too much, when one considers my 77 years. Perhaps you fellas need a younger secretary. I know of several of us who would make good secretaries, and many who would not. I recall Carole Clarke, 50 years secretary of the Class of 1921, who said at one time, "A secretary should be, and often is not, chosen with extreme care. Nothing is worse for all concerned than a half-baked Secretary."

By Golly, just received, an all Italian technical magazine, "Le Prada." My knowledge of this language is, nonexistant, but I found one article in both Italian and English, by our own **John Wiley** entitled, "The struggle between the environment and the economy. Can airport experience teach us something?" It is a down to earth, solid, practical story on the facts, with recommendations on how to design airports in the future. John reiterates the need for a far-seeing "Master Plan" for the long future. If any of you are interested, I will make a few Xerox copies and send them to any who ask. You have only to specify which language.

Please allow Leona and I to wish you all a very happy, merry Christmas and New Year. We all have a lot for which to be thankful. — **Warren J. Henderson,** Secretary, 1079 Hillsboro Beach, Pompano Beach, Fla. 33062

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My thanks to **George Bull** for taking over while I was away. Apparently the *Review* was not aware that I was back so he also got tagged with the October/November issue notes — I must try this more often.

I had the pleasure of attending the Alumni Officers Conference in September and one of the highlights was the presentation luncheon where our **William H. Mills** received one of the 1975 Bronze Beaver awards. His citation reads: "His leadership in Club, Fund and Educational Council activities in St. Petersburg was complemented by one of the longest records of continuous service on the Visiting Committee for Civil Engineering; in these and other ways he has made invaluable contributions to the Association and the Institute in local, regional and national activities. His wisdom, dedication, enthusiasm and benefactions have immeasurably strengthened his alma mater." I am sure I was applauding for all of us at his award; it is always good to see a classmate receive one of these symbols of high appreciation.

Retirements continue to be a source of news for us; one was on July 31 when **Walton W. Hofmann** concluded some 41 years of service with the Bethlehem Steel Corp. Walton went with the company and spent twenty years at their Johnstown plant. Holding various positions, he was assistant chief engineer when he was transferred to the West Coast in 1954. He became chief project engineer and then in 1956 was returned to his home office. There he served on the staff of the vice president for steel operations, became involved in capital appropriations, and in 1967 was made supervising engineer of construction.

Walton is a life member of the American Iron and Steel Institute, has been active in the Masons and the U.S. Coast Guard Auxiliary and is a past president of the M.I.T. Club of Lehigh Valley. He and his wife Edith expect to stay in Bethlehem for the near future but will spend more time on a new project — boating. They have a diesel-powered trawler and plan to use it on the inland waterways and possibly, the open seas.

To William H. Mills, '34 (right), the 1975 Bronze Beaver Award from Howard L. Richardson

Another member to join the ranks is Dr. **Ralph Brown,** who since November, 1974 has been tapering off his activities with the group which operates the emergency services for a Springfield hospital and spending more time rebuilding a lovely old house down here on the Cape. Ann has also retired from teaching so they can devote more effort to the house. Jane and I were over recently for a visit and had a pleasant evening, marred only by the news from Ralph that about a month previously **Johnny Westfall** had suffered a moderately severe heart attack. He was out of the hospital and home recuperating but things are complicated because Frances' heath is not too good either.

An interesting item came in a note to the Institute from **Dillard Jacobs** who received an M.S. in Course X-A with us in 1934. He is at Vanderbilt University where he has written a book *10^2 Years* on the history of their school of engineering in connection with the centennial of the university. He adds the comment that nearly one-tenth of the current engineering faculty have some connection with M.I.T.

Long before Women's Lib and affirmative action "quotas" were ever thought of, Margaret Chase Smith showed what women could do in the area of politics. We are now helping — somewhat second hand — as **Merlyn Richardson** writes that his wife Eleanor won her election in November, 1974 and is now a Georgia State Representative from District 52 in the General Assembly (House of Representatives). Can't you see an argument nowadays in the Richardson household. He starts to talk back and is told, "Shut up, you're out of order!"

I must report the loss of Dr. **Charles F. Pentler,** of Cupertino, Calif., who died this past February. I would express sympathy from all the class to his family.

The August issue had some notes about our own travels abroad in late spring. Since I don't want you to think I never made it back I will take the liberty of adding a few comments on the rest of the trip. We did get to Ely and Cambridge and then across to the Cotswolds which looked much prettier in the

From Howard L. Richardson, '31 (right), President of the M.I.T. Alumni Association, to G. Peter Grant, '35, the 1975 Bronze Beaver at the Alumni Officers' Conference: "As Educational Counselor and Honorary Secretary, President of the M.I.T. Club of New York, Special Gifts Chairman, Regional Vice Chairman of the Second Century Fund, and Class Agent, he served with distinction; and for the past nine years, as Director of Clubs, he has become known and respected by thousands of alumni around the world."

sun than they had two years earlier in the drizzle. Chester is somewhat of a disappointment when you find out that almost all the Tudor half-timbering was really done in the Victorian era, but it does look better than what the Victorians designed on their own.

We went on to York where I was able to visit a model railroader and where, on a drizzly day, we finally got to the Minster. It is a truly wonderful sight — its windows contain about half of all the medieval stained glass that still exists in Europe. We arrived in Inverness on June 2 and found that the day before they had rain, sleet, hail, and snow! This was where I could do some ancestor hunting so we went to Culloclen, where Prince Charlie had his final defeat in 1745. We found that my ancestor had commanded one wing of the Scottish army.

The weather was fine for driving down the Great Glen (Loch Ness is pretty but I hadn't enough to drink to see the monster). We had found the "bed and breakfast" places good for staying in the smaller towns and our weather held for our drive through the Pass of Glencoe and on to Edinburgh. Here we dropped the car, saw the other half of the Royal Mile, and back to London by train. We had five good days there, highlighted bv a trip to Hampton Court (these are real Tudor buildings). Just to show what we think of superstition we came home on Friday, June 13. And now we're stealing candy from children and pennies from blind men, to lay away for a future jaunt.

We took a trip to Mystic, Conn., to the christening party of Mora and **Eric Isbister**'s first grandchild. The proud father is their second son, Eric Duncan, who has just graduated from Worcester Poly and is working for the Electric Boat Co. — **Robert M. Franklin,** Secretary, Satucket Rd., Brewster, Mass. 02631; **George G. Bull,** Assistant Secretary, 4961 Allan Rd., Washington, D.C. 20016

35

The reports are still coming in from those who attended our 40th and had such a good time. Here is the latest, from **Lester Brooks** in East Norwalk, Conn.: "I should have written long before now to report that my bride and I had an absolutely delightful time at the June reunion. It was wonderful to see old friends and to reminisce. What **Ned Collins** et. al. arranged was unbelievable and for the first time I think we participated in a reverse rip-off. If this is the way we're going to be treated in our old age, I'm ready to retire right now.

"It's hard to believe that summer is gone. Ellen and I kept busy entertaining our assortment of six grandchildren from out of state who look forward to fishing and swimming at our summer cottage in Bethlehem, Conn. I must admit that the excessive heat and humidity slowed us up at times. If anything, my job as Product Manager at R.T. Vanderbilt is calling for more and more of my time, but I'm sure this is the case with most everyone these days. My sincere thanks to all of those who did such a wonderful job arranging for our reunion."

Bissell Alderman sent along to me several letters he received in answer to his reminders of the reunion. **Brydon S. Greene** wrote from San Francisco: "For the first 25 years after graduating from Yale, I contributed each year to both M.I.T. and Yale. I also was chairman of a fund drive for M.I.T. in suburban Philadelphia 11 years ago that raised a record amount. Now I am founder of a unique liberal arts college just north of the Golden Gate, called World College West (a prototype for the independent liberal arts college of the future). Of necessity I am contributing very heavily to this endeavor. It will not be possible for me to attend the 40th Reunion but please give my best regards to **Lykos, Paul** and **Sellew** — I remember them with affection. I am now retired from the advertising profession almost three years and enjoying a very active life here in San Francisco which we love — hope you visit here soon. We travel a good deal — last year India, Iran; the year before East Africa, etc. Travel is our joint hobby, besides lots of golf and work on three boards. I'm also in partnership with my nephew, a developer in Marin County, and jointly we have built and own two 30,000 sq. ft. office buildings (two-story suburban garden type), and have two other properties for commercial development when money becomes less tight." . . . **George Lykos** wrote to Bissell, "I was pleasantly surprised to receive your letter regarding the 40th Reunion. I had written **Bob Forster** some time earlier that I would not be able to attend. I feel the trip might be a little too strenuous for me at this time due to open heart surgery not too long ago. It would be so nice to see you, **Sam Paul** and **Frank Sellew.** We must make it a "must" for our 50th. I was rather shocked to see the number of architects left in our class when I received the complete roster of 1935 graduates. I just wonder if the list is correct. For example, **George Hatch** is still very much alive and kicking right here in San Diego and I am sure that **Frank Sherlock** is still going strong as Planning Director of the City of Long Beach." . . . **Al Alschuler** wrote that he and his wife were leaving for the Orient and India and were not sure of getting back in time for reunion. . . . **Les Fitz Gibbon** wrote that he was playing in the International Club Team (tennis) matches in Biarritz and would not be back in Boston until after Wimbledon in July.

Other bits of news through the Alumni Fund office include: a message from **Louis Baldwin** says that he just got his 25-year pin at DuPont and is about to become a grandfather for the first time. . . . A note from **Ed Gregor** says, "Had a major heart attack in July, 1973, which restricts my activities. Retired, I spend six months in Florida and six months in Brooksville, Maine. Sure wish I could be on hand to hoist a stein for '35." . . . **Miller Wachs** wrote: "I retired from Sikorsky Aircraft after helping the helicopter mature from infancy over a 32-year period. I'm doing consulting, primarily in the field of reliability and maintainability." . . . From **George Morrissette** comes, "Since '53 I have been in Louisville, Ky., first with the Reynolds Metals and now with G.E. I have two sons and one grandson." . . . **Barclay Bloomgarden** writes, "Still living on the farm, running farm machinery, business, general repair garage and body shop. I have two beautiful granddaughters. After battling the zoning board, we have our own private air strip on the farm, our plane, and both sons are pilots."

We are down to the semi-finals of the Class Golf as this is written. **Al Johnson** won the Consolation Flight to go into the semis against **Bill Bates,** with **Dick Bailey** and **Bob Flood** in the upper bracket. The President's trophy is currently held by **Ham Dow.** I wish you all a Happy Hanukkah and Merry Christmas. Write soon. — **Allan Q. Mowatt,** Secretary, 61 Beaumont Ave., Newtonville, Mass. 02160

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Plans for our 40th Reunion are well underway. Respondents to the questions raised by Chairman **Henry McGrath** favored a weekend in the Berkshires to the other alternatives. Gathering at Jug End after Alumni Day at the Institute will give us two days for sports and socializing in a delightful setting without putting us in the poor house. Remember the dates: June 3 to 6, starting in Cambridge and adjourning to the country after the close of Alumni Day events. Jug End will expect us for a late dinner and transportation arrangements will be made if needed. Further details will be forthcoming. Meanwhile Chairman Henry is retiring for the second time as of December 1 so we can expect him to devote his energies to making this the best reunion ever.

Roger LeBlanc reports that he has been totally disabled since 1968. He and his wife of 35 years, Marjorie, are happy to have their three children living within 15 miles of their home in Manchester, N.H. Roger would be most pleased to hear from any classmate in the vicinity. His address is 117 Clarke St. (03104), telephone (603) 622-0794.

The less frequent publication of the *Review* means that generally I can read the notes as published before I have to write the next. That way, you can correct your mistakes in an orderly fashoin. I apologize for omitting **Elliott Robinson**'s last name from my copy in the last issue. Elliott was also present at Alumni Day.

At the Alumni Officers' Conference in September **Edward W. S. Nicholson,** a graduate member of our class, received a

To Edward W. S. Nicholson, S.M. '36, the 1975 Bronze Beaver Award from Howard L. Richardson, '31 President of the Alumni Association

1975 Bronze Beaver for "his ardent and in novative efforts as member and leader of the Educational Council (which) have benefited countless students and have brought luster to the image of his alma mater." . . . **Raymond Woodrow,** Director of the Office of Research Administration at Princeton University has been elected a director of the Research and Development Council of New Jersey.

I am sorry to have to report the death on July 19 of **Jack I. Hamilton** in Cleveland. Jack started his career with Curtiss-Wright, Inc. and held executive positions with three California aircraft parts firms before becoming vice president for marketing at Cleveland Pneumatics Company in 1966. The firm specializes in aircraft landing gear. He was a vestryman at Christ Episcopal Church in Shaker Heights and active in many civic organizations. He was an active participant in the M.I.T. Club of Cleveland and a faithful solicitor for the Alumni Fund. To his wife, Polly, and children, Mrs. John Hanna, Richard Hamilton, Stephen, Lawrence and Peter Raymond, the class extends sympathy.

To fund our reunion planning you will shortly be asked to pay class dues. Please be generous with your dollars to the class treasury and your news to the class secretary who is always hungry for such low calory goodies. — **Alice H. Kimball,** Secretary, P.O. Box 31, West Hartland, Conn. 06091

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Edwin L. Hobson has recently been elected President and Director of Aladdin Synergetics, Inc. Alladin Synergetics manufactures and markets food service systems to more than 650 health care institutions in the United States, Canada and Europe. Hobby joined Aladdin in 1969, after 21 years at Monsanto where he held various positions including Vice President of Marketing in the Gering Department and Director of Sales for the Plastics Division. . . . **Ben Holt,** president of the Ben Holt Co., an engineering and construction firm in Pasadena, Calif., has been elected a Fellow of the American Institute of Chemical Engineers. . . . **Robbins H. Ritter** was recently remarried. His bride's name is Kelley Albany Ritter. Their address is 2021 Grismer Ave., #39, Burbank, Calif. 91504.

It is with sadness that I report the death of **Donald E. Kerr** on May 20, 1975. — **Robert H. Thorson,** Secretary, 506 Riverside Ave., Medford, Mass. 02155; **Lester M. Klashman,** Assistant Secretary, 198 Maple St., Malden, Mass. 02148

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Our traveling ambassador, **Don Severance,** reports that **Ken Brock** and he had an enjoyable evening with Henri and **Harold Strauss** in Santa Monica on July 29. . . . **Ben M. Siegel,** in collaboration with Donald R. Beaman, wrote *Physical Aspects of Electron Microscopy and Microbeam Analysis* which was recently published by John Wiley & Sons. Ben is Professor of Applied and Engineering Physics, Cornell University, Ithaca, N.Y. . . . Rev. **William G. Guindon,** S.J., of Boston, has been appointed Dean of Jesuit School of Theology in Chicago. . . . **Frank S. Atwater,** 59-year-old chairman of the Fafnir division of Textron, Inc., was named president of the Homelite division. . . . **Joe Vallone** passed away this summer. Joe had directed the Rhode Island State Department of Public Works for some years, where he had been involved in the planning and construction of some of Rhode Island's major freeway projects. In January, 1974, he was appointed secretary of the state Board of Elections, a position he held until his death. — **A. L. Bruneau, Jr.,** Secretary, Hurdman and Cranstoun, 140 Broadway, New York, N.Y. 10005

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Billie and **George Cremer** are just back from another trip to Europe, this time vacationing for a month as they drove in and out of the villages on England's south coast between Brighton and Land's End. . . . **Al Schreiber** uses San Clemente for his base of operations for his electronic equipment manufacturing company; he shares his ocean beach with our former President. . . . Sybil and **Bob Saunders** make their home in Atlanta, Ga., and this makes it convenient to pursue their hobby of sailing on nearby beautiful lakes. In-between-times Bob continues to soften understandings for the rest of us — which is another way of saying he spent the first 30 years of his career in the carpet business and now has been for seven years consulting in the same.

Jean and **Sid Silber** enjoy a beautiful home in Baltimore. Now can be revealed the reason why they both did so well in tennis at our last reunion: they practice on their own court about four times per week. The hardship of this physical exercise is mitigated by the fact that they can recover in their pool which is alongside. Their son, Paul, a superior young charmer, operates his own large greenhouse on the premises and handles the comprehensive and integrated landscaping. In his spare time, Sid works at his third career since college. His first was at building airplanes; his second was in the bakery business, where he became nationally famous and was elected to the Young President's Club; and the third is developing real estate ventures.

Bill Wingard came over to the Silbers for dinner the night Hilda and I were there; Anita had gone to New England and Bill invited us to spend the night at his house nearby. The next morning Farmer Wingard went out to his garden to pick fresh chives and parsley and then Gourmet Chef Wingard used them to prepare a delicious scrambled egg breakfast for us, which we enjoyed on his screened porch on a pleasant summer morning. While Bill runs his machine shop as primary vocation, we recommend him to Dick Cella and others who may have interest in hiring a top-notch chef and host.

Martha and **Phil Epifano** continue in Bridgeport where they, too, have a palatial estate, part of which includes a Japanese garden complete with boulders placed artistically around a meditation pool which is fed by a specially-created babbling brook. Phil is President of the E and F Construction Co., which has built many schools and churches and which now is doing a new sports stadium for the area. . . . Dotie and **Bob Casselman** spent part of the summer vacationing at their second home on Cape Cod. Bob was considering several offers for creative new jobs, commencing in the autumn, and we are waiting for the announcement of his choice.

Bill DeLia uses Northville, N.Y., as a base for building roads and highways in the Adirondack area. My uncle lives nearby, and he says Bill's company is well known there for its highest-quality work, so we send to Bill our congratulations. . . . **Mark Magnuson** lives now in Cleveland where he is in his 36th year with National Lead Co. Mark said he sees **George Mitchell** occasionally. Mark said his brother, Charlie Magnuson, lives in Kankakee, Ill., where his work is to direct the technical activities of the Armstrong Cork Co. **Lawrie Fabens** was vacationing at Hilton Head when we passed through Cleveland. . . . Aletta and **Bob Touzalin** continue to make their home south of Chicago near Crete. They liked the plan of their Cleveland house so much that they had a carbon copy built for them when business required them to move westward. They located their new home (strategically) just off the 14th tee of a private course, and they now enjoy playing an extra four "warm-up" holes before they tee off for record play. Bob continues to shoot par golf and wedge in some time in the mahogany halls of Interlake Steel Co.

We were saddened by news that **Dave Bartlett** passed away after illness at Tulsa, Okla. His business career included work in several oil and gas businesses, and he made special contributions to our country through his activities in both state and na-

Howard L. Richardson, '31 (right), President of the M.I.T. Alumni Association, awards James S. Rumsey, '40, the 1975 Bronze Beaver at the Alumni Officers' Conference

tional politics. He was Treasurer of the Republican Party and active in campaigns which resulted in the election of his brother, Dewey Bartlett, to Governor of Oklahoma and United States Senator. — **Hal Seykota,** Secretary, 335 Second St., Atlantic Beach, Fla. 32233

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Nostalgia: Classmates will remember the bright new days of the Sailing Pavilion, now 38 years old. It's due for extensive repairs and improvements, even to locker rooms for men and women and power lifts for the craft. And remember the wonderful dinghies — wooden and heavy? Now it will be the MARK III, fiberglass and computer-designed, touted to be superior in performance.

Faculty: Professors **Samuel A. Goldblith,** Director of the M.I.T. Industrial Liaison Office, and **J. Herbert Hollomon,** Director of the Center for Policy Alternatives, discussed resources problems and policies at the San Francisco Regional Conference for alumni and business folks on September 25.

Alumni Fund: 1940 alumni, with 48 per cent of 510 "possibles," accounted for a gifts of $131,000 to the 1975 Alumni Fund.

Top Kudo: **James Rumsey** was awarded the 1975 Bronze Beaver in recognition of his service to the Alumni Association (as a Director) and as a leader of club activities in the Philadelphia-Wilmington area.

Bouquets, also: **Adolph Sebell** is the new President of the Housewares and Home Furnishings Division of Dart Industries. **John Dwyer** is promoted to Vice President - Western Hemisphere Engineering of the M. W. Kellog Co., a division of Pullman, Inc.

Fiscal: **Edith** and **Edward Kingsbury** report the 35th reunion budget of $1,500. This leaves our class with a nest egg of $450 as we look toward the important 40th reunion in 1980.

Deadlines: Class notes are made ready two months in advance of publication. If you have timely information you wish to see in the February issue, now is the time to send it to: **Frank A. Yett,** Secretary, 254 S. Euclid Ave., Pasadena, Calif., 91101

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Our adopted Classmate **Charles Townes** — who was made a member of our class at our 25th reunion — responded recently to my inquiry as to what he was "up to now." As you know he was provost at M.I.T. when he received his Nobel prize award. Here is an excerpt from his letter, "Since 1967, I have been University Professor of Physics at the University of California, a position rather similar to Institute Professor at M.I.T. except that in some way I am supposed to serve all nine campuses of the University. My primary research work has been concentrated on astrophysics, in particular on developing new techniques and observing at infrared and microwave frequencies. In the last few years, this has kept my students and myself fairly busy at observatories on Kitt Peak, Ariz.; on top Mauna Kea, Hawaii; at Cerro Tololo, Chile; at Onsala, Sweden; at the Naval Research Laboratory's Observatory on the Potomac, and at Haystack back in good old Massachusetts, as well as the Lick Observatory and Hat Creek, both University of California Observatories. We have been working particularly on the structure and history of our own galaxy.

"Non-academic activities have involved considerable government consulting, especially in connection with the space program but also in other capacities, and also serving as Director of General Motors and of the Perkin-Elmer Corporation."

Thanks for the news Charlie. There has not been any other correspondence but I'm not ready to succumb to the nihilistic thoughts expressed in the following poem by Howard Nemerov.

"We who survived the war and took to wife
And sired the kids and made the decent
living,
And piecemeal furnished forth the finished
life
Not by grand theft so much as petty
thieving —

Who had the routine middle-aged affair
And made our beds and had to lie in them
This way or that because the beds were
there,
And turned our bile and choler in for
phlegm —

Who saw grandparents, parents, to the
vault
And wives and selves grow wrinkled, grey
and fat
And children through their acne and revolt
And told the analyst about all that —

Are done with it. What is there to discuss?
There's nothing left for us to say of us."

The middle-age syndrome may be setting in but I don't believe it. What do you say? — **Henry Avery,** Secretary, U.S.S. Chemicals, 2863 — 600 Grant St., Pittsburgh, Penn. 15230

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Ranulf Gras and his wife and three children just finished a six-year round-the-world cruise on their 60-foot ketch, the "Merry Maiden." The route was south through the Caribbean, then along the coast of Venezuela and Brazil, southeast across the Atlantic to South Africa, eastward through the Indian Ocean, a zig-zag pattern through the Solomon Islands north of New Guinea, across the South Pacific to Panama, back through the Caribbean and home. Stop-offs included two months in the Galapagos Islands, six months in French Polynesia, and a visit to Honolulu for repairs. Ranny's 21-year-old daughter, Robin, met and married a sailor in Tahiti so the crew returned one member short after what must have

Social Responsibility: Toward Full Corporate Involvement

Would the loss, or diminished capacity, of "the few leading private universities in the U.S." have a significant impact on the country?

Convinced that the answer is yes, Robert C. Gunness, Sc.D. '36, Vice Chairman of Standard Oil Co. (Indiana), has taken a leading role in the Committee for Corporate Support of Private Universities — a group of major business leaders who have come together "to encourage the corporate community to provide very special support to a few very special private universities."

But Dr. Gunness is not advocating uncommitted corporate largesse. To him, corporate social responsibility must be a complex of intentions fulfilled by every operation in which a company engages. "Social performance must be built into corporate operations the same way that profit performance is," he writes in the winter issue of *Business and Society Review*.

How is such a philosophy consistent with the aims of the Committee for Corporate Support of Private Universities? Let corporate support take the form of involvement as well as dollars, he writes. Support "innovative approaches that address the causes of social problems, not merely their symptoms — approaches that are reproducible and will challenge the status quo in . . . areas where our present approach is out of touch with the times."

It is on the basis of a test such as this that Dr. Gunness presses for corporate support of "the pace-setting private institutions with outstanding graduate schools" — a "national asset," he says — through the Committee.

To Robert C. Gunness, Ph.D., Vice-Chairman of the Board of Standard Oil Co. (Indiana), *"corporate social responsibility" means more than corporate largesse for do-gooders. The problem, he says, is to "to find ways to make the corporation itself profitably responsible and responsive to emerging social expectations."*

been a fabulous experience.

Bernie Levere reports a shorter cruise to Indonesia with visits to Singapore and Bangkok. . . . **Edward W. Smith, Jr.**, is the photographer and compiler of a new volume entitled *Workaday Schooners* recently published by International Marine Publishing Co.

Charlie Smith, immediate past Board Chairman of the Chamber of Commerce of the United States, has been elected Chairman of its Executive Committee. . . . Captain **W. C. Fortune** writes that he is "on his third career and starting a fourth." How about a little more specific information on this? . . . **John Whitman** is still involved in Washington, D.C., has one son in Harvard and another in Tufts. . . . **Aniceto Santos** is now a Director and Vice President of Ishikawajima do Brasil Estaleiros, S.A.; he was recently elected to the Technical Committee of the American Bureau of Shipping.

Antonio C. Kayanan is a planning consultant on Missions of the United Nations and of the World Bank; he recently received from President Ferdinand Marcos a plaque as "Outstanding Filipino Overseas" in the field of science and technology. **Jerry Coe** visited **Frank Seeley** in Miami recently and tells us that Frank is Chief of Roadway Lighting for Metropolitan Dade County and is also teaching at a local college. Frank has both a P.E. certificate and a Master Electrician's license; but he says these could not have been predicted by his effectiveness in Course VI subjects!

Had lunch with **Morrie Steinberg** in Burbank in September. Morrie's current position in the Lockheed corporate organization is Director, Technology Applications. Apparently this means traveling all over the world looking for all sorts of new business ventures for Lockheed facilities and expertise. . . . **George Schwartz** did a really outstanding job as General Chairman of the 1975 Alumni Officers' Conference. Also saw **Charlie Speas, Lou Rosenblum, Geza Neuman, Hugh Schwartz, Paul Hotte,** and **Jim Littwitz** there.

Best wishes for a Merry Christmas and a Happy New Year. — **L. K. Rosett,** Secretary, 191 Albemarle Rd., White Plains, N.Y., 10605

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Two of our classmates went through the Supreme Graduation since our last report: **Kjeld "Kelly" Damsgaard,** and **Malcolm "Mal" Kispert.**

Kelly's daughter, Ann, sent the following touching report: "Kjeld Damsgaard died suddenly on Friday, May 9, 1975, of a heart attack. Kjeld was Vice President of the Liquified Natural Gas and Specialty Vessel Product Group and also in charge of the Industrial Sales Program at the Sun Ship Building and Dry Dock Co. in Chester, Penn., where he worked for 29 years. He is survived by his wife Dorothy, his daughter, Ann, and his son, Kell. Many of you may remember Kjeld waiting on table at Walker, wrestling on the school team, or participating in the Dorclan Society. The spunk and vitality and twinkle in his eye which he displayed at school continued to characterize him throughout his life. Kjeld will be best remembered for his unimpeachable integrity and his warmth of spirit — which are just about the most important attributes a man can have."

Mal Kispert passed on unexpectedly at his home in Dover, Mass., on September 13. The obituary appearing in the Institute Review section fills us in on his activities and accomplishments in later years.

Many of us recall with pleasure our numerous contacts with both these men in the dorms, on campus, and in subsequent encounters through the years. Fortunately, memories never die — and we can always enjoy our memories of these two grand guys.

On a happier note, some of you may have seen the article on M.B.A.'s in the June 30 *Business Week*, in which **Frank E. Carroll,** President of Decks Inc., Rolling Meadows, Ill., comments on the effects of the current recession on his business. Fortunately, Frank is taking the recession in stride, despite the fall-off in orders. . . . **Ken Scheid,** president of K.G.S. and Associates, Pittsburgh, ("comprehensive graphic arts consulting and administration") writes that his business "is an up and down situation. Frankly, I count on my investments to stay afloat. But the sorts of assignments we've had, coast to coast, have been very interesting with all sorts of organizations like colleges, firms, associations, religious institutions, governments, etc. By the nature of things at K.G.S. and A., in my non-client hours I've built a considerable skill as a monetary and inflation economist. If you want to know what will happen to the price level, ask me. (Or Friedman.) And it may surprise you to know that I am now becoming, I believe, a specialist on matters, economic and otherwise, about the Peoples Republic of China. . . ." Ken's *tai tai* (that's Chinese for "wife"), Minette, is exercising her liberation rights by working on the staff of the psychology department at Pitt. Their oldest daughter seems settled in southern California, and their younger one will start college out west next year.

For the moment, that covers the news in hand. Do let me (or the Alumni Office) know your doings — and may they all be *happy* doings. — **John L. Hull,** President, and Secretary (until assassinated or otherwise replaced), Hull Corp., Hatboro, Penn. 19040

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Back in 1950 your Secretary promised himself he would write Reunion Notes at reunion time, not four months later; here it is 1975 and as yet this poor habit continues!

The 30th Reunion at Chatham Bars Inn was blessed with good weather despite the rains encountered in Cambridge on June 6. Yes, the shawls, sweaters and foul weather gear of Friday were displaced — by a few, at least — by bathing suits on Saturday and Sunday. All in all, a most pleasant Spring weekend at the Cape with congenial friends and acquaintances.

Fifteen or twenty of us grouped together at Pops on Thursday evening enjoying the several nectars dispensed by both Maestro Fiedler and Johnny Barleycorn. A part of this group together with others enjoyed the Cambridge activities on Friday before traveling to Chatham for the usual "let's get acquainted" cocktail hour. We had the good fortune to be lodged in several guest houses about the complex which provided countless rendezvous locations throughout the weekend.

Informality was the plan of the day with little or no structure in the program; in fact, there was little or no program despite the herculean efforts of **Charlie Patterson,** Program Chairman. Beachcombing by many, golf by a limited few, tennis for a somewhat larger contingent, antiquing for the hearty, and gift shopping proved to be our activity.

Appropriate trophies were awarded for such important activities as golf, tennis, swimming, longest distance traveled, etc. The "cute chick award" drew the greatest attention; in the interest of harmony your Award Chairman (only attendees know his name!) turned coward and awarded the trophy to one of our cute waitresses.

An informal relaxed weekend attended in whole or in part by the following classmates and wives: Jean and **Chris Boland,** Billie and **Al Bowen,** Ellen and **Jim Brayton,** Gerry and **Buzz Busby,** June and **Frank Donohue,** Kate and **Jake Freiberger,** Dee and **Frank Gallagher,** Den and **Rey Grammer,** Nancy and **Charlie Hart,** Lou and **Pete Hickey, Donald K. Kuehl,** Margaret and **Don Lovell,** Ann and **Bob Maglathlin,** Anne and **Andy Marcocchi,** Jeanne and **Bill Martin,** Jan and **George McKewen,** Louise and **Tom McNamara, William J. Meade, Arthur E. Miller, Warren H. Miller,** Jan and **Charlie Patterson, James B. Pickel,** Mary and **Gerry Quinnan,** Marge and **Bob Schumacher,** Elaine and **Bill Shuman,** Betty and **Al Shelby,** Fran and **Clint Springer,** Elinor and **Ed Stoltz,** Mary and **Dave Trageser.**

Although there continues to be a communication gap amongst our group (my kids say it also exists here at home), the following items have been accumulated over the summer: In mid-August, Ann Maglathlin advised that Raytheon had at long last fully recognized new Class President Bob's ability! Effective August 1, Bob was appointed Director of Development Engineering at Raytheon wherein he shall assist the vice president of engineering in the supervision of the company-wide Independent Development Program and in bringing various elements of the company together in the solution of major technical problems, particularly in radar and related fields. Congratulations! . . . **George K. Turner**'s wife advises that George has started a fluorometer business in his garage. She thoughtfully adds, "come and see for yourself if you're in California!" . . . Billie and **Al Bowen**'s son, Gregg, married Guynoir Kratka of Long Beach, California in late August. Twenty-five year reunion attendees will remember that Gregg spent the weekend on the Institute tennis courts!

In late July the Boston Sunday *Herald Advertiser* included an interesting article as regards the Ninth Annual Tartan Regatta and as a Tartan 27 owner, the article proved to be of great interest to this writer — especially when I learned that **Hal Thorkilsen,** President of Ocean Spray Cranberries and a resident of Duxbury, was participating for the ninth time as skipper of his Tartan 34 "Amerika." Yes, there are those who will say that Hal cannot spell yet I suspect that it is the Scandinavian in him! . . . After several years with Cabot in Iran, Suna and **Art Hall** have moved to Sao Paulo, Brazil where Art will be Cabot's Director of Latin America operations. Suna's late spring letter proved most remarkable as she described the sev-

eral differences in living habits between the likes of Tehran and Ahwaz in Iran and the late fall-early winter of Brazil. Wow! . . . In mid-July Dr. **Richard B. Marsten,** Director of Communications and Data Management Programs for N.A.S.A. became Dean of the City College School of Engineering in New York City. Dick will also hold the rank of Full Professor in the College's Department of Electrical Engineering.

Frannie joins me in wishing you and yours a Merry Christmas and prosperous New Year. — **Clinton H. Springer,** Secretary, P.O. Box 288, New Castle, N.H. 03854

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Bob Spoerl, our 30th reunion chairman, has announced the dates for the 1976 reunion. **Ned Tebbetts** has been kind enough to forward this information to me from Bob. M.I.T. has been encouraging quinquennial reunions to be held on the campus by providing dormitory and dining facilities at considerably lower cost than could be obtained for comparable accommodations. The reunion weekend will be held on campus and can begin as early as Wednesday, June 2, and will last to Sunday, June 6. An M.I.T. night at the Pops and Symphony Hall will be included as well as a number of events in the Boston area to celebrate the "Bicentennial Celebration." Bob Spoerl is busy organizing his committee and you will soon begin to receive information in direct mailings from this group. We will keep you abreast of the planned activities in these class notes between now and June, 1976.

Ned Tebbetts attended the annual M.I.T. Alumni Officers' Conference on September 12 and 13 along with classmates, **Jim Goldstein, Herb Hansell, Mort Bromfield** and **Mrs. Thomas F. Curley.**

Alfred A. Little and his wife, Marian, have lived in the Philadelphia area since graduation. They were married in 1949 and have four children, Patricia (University of Chicago '75), Alfred (Cornell '77), Nancy (Penn State '79), and Carrie in the seventh grade. Al has been with G.E. most of his working history (1956-1972) and 1973 to the present. He has been primarily a manager in aerospace and some medical systems. He is now managing a manufacturing function in electrical equipment (circuit breakers). The most dramatic single assignment was his work in the first recovery of a spacecraft. During the years 1946-1956 and 1972-1973 Al worked as a Navy civilian employee, running an aircraft and missile structural test facility.

Al is on the faculty of Widener and LaSalle colleges. He is an officer of the Appalachian Mountain Club and an avid white-water kayaker. He is an officer of the Delaware Highland Gathering and Scottish Games, and he and Marian are enthusiastic Scottish country dancers. They are also active in the Unitarian Church. Al is looking for a new job offering where he would have greater opportunities to contribute. Any leads the classmates could provide would be greatly appreciated. His address is 461 Paxon Hollow Rd., Media, Penn. 19063.

Edward L. Belcher has been elected president of Caldwell Mfg. Co., Rochester, N.Y., a manufacturer of window hardware. Ed, an old buddy of mine while working together on *Technique,* joined Caldwell in 1956 as production manager. He was made vice president in 1958 and executive vice president in 1967. Ed has been active in local politics, is chairman of the Memorial Art Gallery Finance Committee, and a member of the Rochester Yacht Club.

Stuart Grandfield has founded his own company, Grandfield Associates, government contract specialists in Santa Barbara, Calif. Until recently, Stuart was Vice President of E-Squared Thermodat of Carpenteria, Calif. Previously Stuart had been with Raytheon of Waltham, Mass., following graduation from M.I.T. and receipt of a master's degree in business administration at Boston University.

Bill Harrington reports that he is enjoying life on their 140-year-old farm. Both of the Harrington children have graduated from college. Bill's plastic packaging display business continues to grow in Thiensville, Wis.

Donald A. Hurter and two other engineers at Arthur D. Little have completed "A Study of Technological Improvements in Automobile Fuel Consumption," commissioned by the Department of Transportation and E.P.A. This report was published in the June, 1975 issue of *Motor Trend* magazine. — **Russell K. Dostal,** Secretary, 18837 Palm Circle, Cleveland, Ohio 44126

Edward L. Belcher, '46

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In September I took my son Bob to New England to look at Dartmouth and Williams. We ended up at M.I.T. for the Alumni Officers' Conference. It was an interesting week and particularly enjoyable to see a lot of friends from the classes of '44 through '49. From our class, I briefly chatted with **Bob Hagopian, Dick Knight,** and the late **Marty Phillips** *(see p. 118),* who are associated with the Institute. I also saw **Claude Brenner** and sat with **Arnold Judson** at the Secretaries' breakfast. Arnold enjoys his work with Arthur D. Little and now realizes that a note on the envelope of the Alumni Fund Contribution comes right through to me. This is certainly an easy means of communication. More of you should use it.

I received a sad but very nice note from Dottie Potter advising of the death of her husband **Richard.** I'll share it with you: "Thought you would like to know that Rich died August 27 in Riverside Hospital, Columbus. His battle of nine years with Hodgkins disease finally caught up with him. He had such guts — even though dragging and feeling rotten these past ten years, he would still take his trips overseas, his last being in May. He worked up until a week before he died, when he entered the hospital. He was my best friend and I feel so lost without him but I know he suffers no more and that is a blessing. He built up the export business at Gorman-Rupp until it became a very important part of the company. He was a success and I'm glad all his hard work had begun to bear fruit. He had such a nice time at the 25th reunion and I'm glad he got to that one anyway. Hope all goes well with you."

I also received a nice letter from **Pedro Picornell**: "Early this year I was appointed a member of the F.A.O. Advisory Committee on Pulp and Paper, which advises the Food and Agriculture Organization of the United Nations on matters concerning the world's pulp and paper industry. I continue as Executive Vice President of Paper Industries Corp. of the Philippines, a position I was appointed to in 1973. This company is the largest in Asia and the first in the world to produce pulp and paper from tropical hardwoods on a large scale. I continue as Vice President of A. Soriano Corp., the largest industrial group in the Philippines, and hold corporate positions in other companies in Southeast Asia. For friends of the Tech Catholic Club days, I was made a Knight of Magistral Grace of the Sovereign Military Order of Malta, the oldest order of chilvary of the Roman Catholic Church, in 1972. I had the pleasure of meeting **Harl Aldrich** and his charming wife here in Manila three weeks ago. He is here on a consulting job for the expansion of the Manila waterworks. Should anyone else decide to come to this part of the world, do drop in."

Jordan Baruch writes that he has been appointed Professor of Engineering at the Thayer School and Professor of Business Administration at the Tuck School, both at Dartmouth. While in Hanover, we had visited with a family friend, at the Tuck School, so we were probably within 100 yards of Jordan without realizing it.

Have a pleasant Christmas. — **Dick O'Donnell,** Secretary, 28516 Lincoln, Bay Village, Ohio 44140

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William J. Weisz, president of Motorola, Inc., was elected a member of the M.I.T. Corporation by the Alumni Association. Bill recently received an award from the Freedoms Foundation at Valley Forge. Their national awards competition program was established to search for worthy efforts which strengthen an understanding of freedom and the fundamentals of a free society, and to honor schools, individuals, organizations and corporations that most effectively advance these concepts. Bill's award was in recognition of an address he delivered before an Eagle Scout dinner last year. In his speech, Bill discussed the importance of profits.

Dan Fink was co-recipient of the Robert J. Collier Trophy for his individual accomplishments in making LANDSAT, the earth resources technology satellite, the outstanding aerospace event of 1974. . . . **Donald H. Archer**'s article on antennas, "Lens-Fed Multiple Beam Arrays," was published in a recent issue of Raytheon's journal *Electric Progress*. Don is a consulting engineer for the Electromagnetic Systems Division, Santa Barbara, Calif. Don was responsible for the antenna and microwave

Howard L. Richardson, '31, President of the M.I.T. Alumni Association, awards the 1975 Bronze Beaver to John W. Barriger, '49 (left) and to Robert W. Mann, '50 (right)

components for the HAWK and Sparrow III missile systems, the Pincushion Decoy Sorting Radar, and the AMRAD tracking radar. . . . **Ed Kratovil** has shifted from suburbia to an apartment in Chicago and is enjoying every moment of city life. . . . **Elliott Bates** is president of Alonyo J. Harrison Associates, Inc., an architectural engineering firm doing work in educational, health, business, industrial, and housing construction, mostly in Maine. His firm has been fortunate to be busy in a field where this isn't always so these days.

Paul N. Anderson, Jr. moved to Winchester, Mass., from Ann Arbor, Mich., in 1973. Paul is heading the Trust Department of Middlesex Bank in Burlington. His son is a member of the class of '75 at the other Cambridge university. . . . **Eugene Purdum** writes that condominium sales are beginning to pick up, so maybe construction of high-risers will begin again — the slump has had a severe effect on his structural design business. . . . **William H. Brauer** and his wife visited Russia last year — what a way to appreciate the U.S.A. Bill would like to send some of our Congressmen, Senators, and union people to see Russia. His son is an honor student at University of Michigan, majoring in mathematics under full N.R.O.T.C. scholarship.

Merle K. Loken is Professor of Radiology and Director, Division of Nuclear Medicine at University of Minn. Hospitals. . . . **Walter Chaiko** sent a note from Princeton where he is employed as Manager of Research and Development Marketing by Ingersoll-Rand. . . . **Maurice Rifkin** and **Leo Celniker** both have sons at M.I.T. . . . **Fred Dunmire** has 26 years at Grumman Aerospace Corp. . . . Commander **Jim Guida** writes of enjoying retirement in Vermont. . . . **Milton Pohl** is a stockbroker with Strasburger, Pearson, Tulcin, and Wolff in N.Y.C. His son Bill is a sophomore at Bowdoin College.

Four of our classmates have died during the past 12 months. **John D. Harms** died December 26, 1974. His widow, Polly Harms, wrote that Don had spent the morning in his office in Charlotte, N.C. During the afternoon he played nine holes of golf. While Don was driving home for dinner he was stricken. He was able to pull into an Exxon station and stop the car before he died of a heart attack. Polly wrote how proud Don was when one of his sons received a Master's degree from M.I.T. Don had sent a contribution to the Institute on the morning he died.

The sympathy of the class of '48 is extended to Don's family and to families of the following three classmates: **Harold MacWilliams, Jr.**, who died of a heart attack on January 25, 1975. Harold was Manager of Industrial Engineering with American Safety Razor Company in Staunton, Va. Notices were received about the death of **Helmut F. Onusseit** of Reading, Mass., and **William D. Stahlman** of Madison, Wis. — **S. Martin Billett,** Secretary, 16 Greenwood Ave., Barrington, R.I. 02806

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Norman M. Klein, who graduated in architecture in 1949, died on June 26, 1975, of leukemia, in Washington, D.C., where he was an associate partner of Skidmore, Owings, and Merrill, and director of the firm's study of urban rapid transit systems for the Congressional Office of Technology Assessment. He tackled many areas during his career: work with the Urban Design Concept Associates, a federally financed team of architects and highway engineers; consultant to New York City's West Side Highway Project; during the 50's, helping develop new zoning ordinances for New York City, involved in the city's first pilot brownstone rehabilitation project, and designing notable homes for friends and clients (some depicted in *House Beautiful, Holiday*, and the *New York Times*); planning the Market Street East project in Philadelphia, an early major downtown redevelopment program; and helping design the Oakland-Alameda Coliseum, home of the Oakland Raiders. During W.W.II, he flew more than 30 missions as lead navigator with the Eighth Air Force in Europe and won the Distinguished Flying Cross and an Air Medal. Our condolences go to his widow, Marilyn, and three children, Stephen, Deborah and Laura.

On a more pleasant note, **G. J. Grott** reports that his personal salt mine, S.W. Salt Co., is finally in the black, having one completed L.P.G. storage cavity of 500,000 barrels, with two more under construction. "Family is well with Edna managing the front office of Steel Engineering, a local company. This year, we have Leslie, David and Beth in college, and Lisa a junior in high school." . . . **Sidney Howell,** executive Vice President of the Weatherhead Co. in Cleveland, was elected to a three-year term as Director of N.F.P.A., the National Fluid Power Association. He and Eileen (of Tech Show fame) were at our 25th reunion last year.

A 1975 Bronze Beaver was awarded to **John W. Barriger** at the annual Alumni Officers Conference in September, with the following citation: "As a dedicated and inspired worker and leader, a Director of the Association, member of the Club Advisory Board and Deputy Chairman of the Alumni Officers Conference, as past president and officer of the M.I.T. Clubs of Chicago and Southern California, as a Class officer and in numerous Fund capacities, his service to the Institute has been extraordinary. He has frequently and with enthusiasm assisted and advised alumni, staff, faculty and the administration of the Institute." Congratulations from all your classmates, Jack; you do us all proud.

Louis G. Peloubet was appointed controller of Union Carbide Corporation in August, moving there from Textron, where he was vice president and controller. He'll be living in Old Greenwich, Conn. and commuting to 270 Park Avenue, the command post of Carbide's world-wide activities.

Clifford L. Noll is now Western Regional Manager, Equipment and Fired Heater Sales, for Foster Wheeler Energy Corporation — the major U.S. subsidiary of Foster Wheeler Corporation — which designs, fabricates and constructs steam generating equipment, process plants and fired heaters for electric utilities, shipbuilders, petroleum refiners and chemical producers. He and Muriel have four children: Thomas and Richard, in college, and Bruce and William, still in Grade School in Littleton, Colo. . . . **Peter K. Stein** is announcing his 115th short course in "Unified Approach to the Engineering of Measuring Systems" in fourteen years, at Phoenix, February 2-7, 1976. Write Peter at Arizona State University for details.

Harry Lambe reports that our class officers had a meeting in early October with Professor Robert Morrison, the Class of 1949 Visiting Professor at M.I.T. this year. So our 25th reunion gift has come to fruition. Harry also reminds us that planning for our 30th reunion has started and that input from classmates — any and all ideas — are requested.

As I finish these notes at the Clipper Club at J.F.K., I am en route yet again from Boston to Rio, a 13-hour journey just tolerable when on a 747 with three or four seats across to stretch out in. Since I left last week, Sonya reports continuous rain. However, summer is on its way and the weather will be delightfully clear — and *very* hot. Best wishes to all. — **Frank T. Hulswit,** Secretary, Rua Barão de Tarre, 263/CO2, Ipauema, Rio de Janeiro, Brazil

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Allen E. Bryson has been with the Atlantic Richfield Co. for the past 25 years — all with its Products Division. He has lived in Arcadia, Calif., since 1972 when Atlantic moved its headquarters. He and his wife, Dorothy, have four daughters — three at home and one at Wheaton College (Illinois). Allen is on several of Atlantic's Speakers Bureaus, teaches a college Bible-study class, and serves on the Emergency Preparedness Sub-Committee of the National Petroleum Council. Dorothy volunteers on the school library staff and teaches a sixth-grade Sunday-School class.

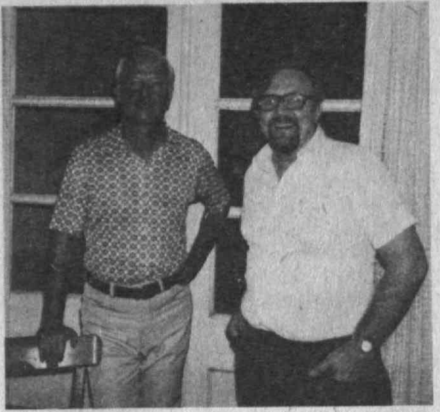
Norman F. Tisdale, Jr., tells us that in November, 1974, he sold his interests in the company where he worked and retired. Norman says it's really terrific! . . . As of 1973, **Charles E. Heinrichs** has been President and owner of R. N. Johnson Co., Wayne, Penn., contractors. . . . **Richard L. Endres** reports that he is presently Employee Development Specialist with the Naval Air Station in Alameda, Calif. He was married four years ago and has a two-year-old son and another child expected soon.

Gerald A. Lessels has been appointed a Fellow in the American Institute of Chemical Engineers, and he received the Institute's Service-to-Society Award in December, 1974, for over 20 years of activities on behalf of equal opportunities for minorities. . . . Professor **James V. Eppes,** who served as a Professor of Mechanical Engineering at Lehigh University for 27 years until his retirement in June, 1974, received the Lehigh Home Club's 1975 "Distinguished Service Award," presented annually by the area Lehigh alumni group for "helping significantly to encourage interest and fellowship among Lehigh alumni and friends."

Karol A. Stark reports that he and Mrs. Stark keep busy in New York (five miles north of Utica) building new pasture for horses — hopes to raise horses soon. Lots of riding trails — over 28 acres. Everyone welcome to visit.

Arch C. Luther was among 12 recipients of the 1975 David Sarnoff Awards for Outstanding Technical Achievenent, RCA Corporation's top technical honor. He received an award "in recognition of his many outstanding technical contributions enhancing RCA's reputation as a leading supplier of television systems." Mr. Luther is in RCA's Commercial Communications System, in Camden, N.J.; his most recent accomplishment was in conceptualizing the design of the TCR-100 video tape cartridge recorder, a professional TV broadcasting system that is said to have "revolutionized short-segment TV program production and TV station break operations" and resulted in last year's "Emmy" Award to RCA Broadcast Systems. Arch now lives in Woodstown, N.J., with his wife and two daughters and a son.

William J. Gallagher, Reliability Engineering, Chrysler Corporation, has been elected a Fellow of the American Society for Quality Control "for early perseverance in introducing methods of statistical quality control into the automotive industry and his sustained efforts therein for over two decades; for his personal efforts in teaching statistical methods and quality control philosophies; and his genuine leadership in the Greater Detroit Section and the Automotive Division." Bill's background includes 25 years in quality control and reliability work for Chrysler, Ford, and General Motors.



"Arise, ye sons of M.I.T., in loyal brotherhood," says the alma mater, and here is an example from Houston, Texas, when Joe F. Moore '52, entertained members of the M.I.T. Club of South Texas early in the fall. The pictures were made by the late Martin M. Phillips, '47, on one of his last trips as Regional Director of the Alumni Association; they show (above left) Mr. Moore (left) and Noa Spears, '48; (above right) John D. Moriaty, '30, and Mrs. Moriaty (left and front), Mrs. Moore, and Louis P. Karvelas, '52, and (left) Harold J. Muckley, '39, Mrs. Muckley, and William F. Herbert, '25 (right).

Robert W. Mann, a participant in M.I.T. activities for nearly 30 years as an undergraduate, graduate student, alumnus, and teacher, received the 1975 Bronze Beaver Award of the M.I.T. Alumni Association at the Alumni Officers' Conference in September. As the award states, Robert's ability to transmit the flavor and excitement of engineering at M.I.T. to audiences in scores of cities has been an inspiration to them and to alumni generally. Most recently, as its President, he led his Class to the largest 25th Reunion and the largest 25th Reunion Gift in the history of the Alumni Association.

Thomas C. Buchanan has been appointed Director of Marketing of the Milford Rivet and Machine Co. in Milford, Conn. He is an acknowledged authority on riveted assembly methods, the author of numerous articles and papers on rivets and riveting equipment. Tom is a Director of the Orange Land Conservation Trust and of the Orange Non-Profit Housing Corporation, a former member of the Milford Representative Town Meeting, and a former director of the Milford Chapter, American Field Service. He lives in Orange, Conn., with his wife, Margaret, and their children.

In November, **Anton de S. Brasunas** and **A. Craig Hood** were selected to be Fellows of the American Society for Metals. Anton is the Associate Dean of Engineering at the University of Missouri-Rolla; and Craig is the General Manager, Special Products Div., Standard Pressed Steel Co., Fort Washington, Penn. — **John T. McKenna, Jr.,** Secretary, 2 Francis Kelley Rd., Bedford, Mass. 01730

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Anthony Ralston has been elected President of the American Federation of Information Processing Societies, Inc. Tony is Professor and Chairman of the Department of Computer Sciences at the State University of New York at Buffalo. He is also the immediate past President of the Association for Computing Machinery. . . . From the U.S. Army Corps of Engineers comes word that

Joe F. Moore, '52, was Chairman of the alumni committee planning the 1974 regional conference in Houston on U.S. energy policy, and nine months later he received from Howard L. Richardson, '51 (right), a Presidential Citation for his committee. "Guided by careful analysis and thoughtful planning, the Houston Conference Committee successfully integrated the requisites of an outstanding local program with the goals of the Institute. Their effort, filled with enthusiasm, wisdom and understanding, produced a conference of enduring value to their community and of great service to the Institute," reads the tribute handed to Mr. Moore at the 1975 Alumni Officers' Conference.

Colonel **Daniel L. Lycan** has become the District Engineer of the Rock Island District, Corps of Engineers. Dan formally served as Commander, U.S. Army Computer Systems Command Support Group in San Francisco. In his new position, he is responsible for federal flood control and navigation works in northwestern Ill., southern and southwestern Wis., eastern and central Iowa, northeastern Mo., and portions of southern Minn.

Corning Glass Works has announced the appointment of **Rodney I. Frost** as manager of ceramic process development in the Technical Staffs Division. Mr. Frost has been technical manager of Corning's automotive emission control project since last year. He joined the company immediately after graduating from M.I.T. and served in several engineering positions before being named an engineering associate in 1972. . . . Litton Industries in Melville, Long Island has announced that **Charles W. Poppe** has been named director of marketing for Litton Industries' Datalog division. Charlie will be responsible for all marketing and sales of facsimile communications systems and high-speed, non-impact printers. Prior to this appointment, he was marketing manager for the Hartman Systems division of A-T-O, Inc. Charlie writes that his son, also Charlie, is a freshman in the Biomedical Engineering/Pre Med program at Duke University. His daughter Wellner is a high school junior and was awarded a National Science Foundation grant; she assisted in cancer research at the Waldemar Medical Research Foundation last summer.

Electronic News has reported that **Harold T. McAleer,** corporate vice president of engineering at the General Radio Corporation, has been named general manager of G.R.'s new Electronic Instrument division. The division is responsible for most G.R. benchtop instruments. Harold continues as a corporate vice president and will be the new division's engineering manager on a termporary basis. . . . **Dan Lufkin** writes that his practice as an environmental consultant brings him a gratifying variety of interesting problems, making him appreciate the value of the solid basics in science and engineering. Dan lives in the northern Md. countryside near Frederick. . . . **Matthias F. Comerford** is now entering his fourth year as a materials and process consultant. He writes that before going into business for himself, he had been manager of the materials laboratory of R.C.A.'s Computer Systems division.

A note from **Dick Wingerson** says that he retired as an Air Force Colonel on January 1, 1974. Dick is now making his home in Crested Butte, Colorado. . . . **Timothy M. Brown, Jr.** is working on the Space Shuttle at the Marshall Space Flight Center. Tim is responsible for laboratory hardware and simulations relating to the vehicle main engines, solid rocket boosters, and external fuel/oxidizer tank. His wife Bunny is now operating the Skyland Camp for Girls in N.C. in the summer. His son Murphy is a junior in high school; the twins, Mike and Sherry, are high school freshmen. Both Tim and his wife are active tennis players. . . . **Richard H. Daly** writes that he is currently manager of a Signal Processing Department at Raytheon's Wayland Laboratory. He is also a member of the Framingham, Mass., School Committee and active in local town affairs. Richard and his wife have seven children, age 1½ to 20 years. . . . **Richard W. Prugh** writes that he is a safety consultant at DuPont, and also President and Treasurer of Hazard Reduction Engineering, Inc., a manufacturer and distributor of a patented appliance tester.

A number of our classmates have been recognized for outstanding performance in various areas. **E. R. Epperson** was recognized as the Outstanding Educator for 1975 of Troy, Ohio. . . . **William J. Manion, Jr.** has recently been made president of the Nes Division of Nuclear Energy Services, Inc., a subsidiary of Automation Industries, located in Danbury, Conn. . . . **Lloyd A. Currie** was awarded a Commerce Department Science and Technology Fellowship for the 1974-75 academic year. Lloyd is serving as a Congressional Fellow on the staff of Congressman Mike McCormack, and as a Science Advisor on the Subcommittee on Energy (House Science and Astronautics Committee), of which McCormack is Chairman.

Jack Larks is acting as president of the M.I.T. Club of South Texas. Jack is also educational counselor and alumni fund telethon chairman. He writes that the number of M.I.T. alumni in the Houston area is increasing, and is now over 700. . . . **Charles H. Ehlers** attended the 70th Advanced Management Program at Harvard University this past spring. . . . Finally, **Stan Buchin** writes that he has merged his company, Applied Decision Systems, into a larger management consulting-education firm, that of Temple, Barker and Sloane. — **Arthur S. Turner,** Secretary, 175 Lowell St., Carlisle, Mass.; **Richard F. Lacey,** Assistant Secretary, 2340 Cowper St., Palo Alto, Calif.

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News is slim. Unfortunately, I must report that a notice was received (with no details) of the untimely death of **Bill Shapiro** on July 28. Should any of you be in a position to provide details, please write to me or *Technology Review*. . . . **Norman Doelling** has been named manager of the M.I.T. Sea Grant Program's Marine Industry Advisory Service, a new focus of the Program's advisory activities for Massachusetts and New England. In earlier years, Norman spent over a decade at Bolt, Beranek and Newman, then worked for General Electric and Digital Equipment Corp., and finally was self-employed in his own consulting venture, serving high-technology American companies who seek business opportunities in Japan. . . . A note from **George Parker** says, "Consulting Engineer with General Electric Ordnance systems, Pittsfield, Mass. Married Carolyn Betts of New Hartford, N.Y., in '59. Three children — Elizabeth, 15; George, 13; and Julie, 1." — **Martin Wohl,** Secretary, 7520 Carriage Lane, Pittsburgh, Penn. 15221

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Norm Rosen retired from the U.S. Army in 1972 and is now Assistant Construction Manager for Bechtel on the Washington, D.C., Metro project. . . . **Roy Handwerk** is "Marketing Manager of the Water Treatment Group" but doesn't say where or with what organization. We can only presume that Roy is still with B. F. Goodrich. . . . We understand that **George Dormer** has started a business in New York City.

You will probably have received your class directory by now. **Wally Boquist** reports that all of the individual data revisions have been made and final typing completed. Some classmates are missing, but with your help, we will track them down prior to the next revision (in 1977). For example: **E. Ken Heist,** a "lost classmate," was located alive and well at T.R.W. in Manhattan Beach. Ken has been married for ten years. Did you know that you were lost, Ken?

Russ Barnes and family (two charming little girls) visited old friends back East during the recent summer; these included **G. Schwenk,** W. Boquist, **S. Hoff,** and **R. Rohner.** . . . We recently called our Class Treasurer, **Bob Evans,** and found that he had been promoted to Dean of the College

A posthumous award of the Bronze Beaver — the highest recognition for alumni service to M.I.T. which the Alumni Association can bestow — came to the late James. M. Chorak, '57, this fall. "A volunteer emissary of the best of M.I.T. in whatever community he resided," said the citation, "he touched many others — fellow-alumni, students, and friends — with the spirit, pride, and enthusiasm he shared for M.I.T." When Mrs. Chorak found she could not be in Cambridge on September 13, John A. Currie, '57 (right), stepped up to receive the Beaver and citation from Howard L. Richardson, '31, President of the Alumni Association, during the Alumni Officers' Conference.

at Brandeis University.

Our 25th reunion planning will get underway this year. **Bob Anslow** has agreed to be reunion gift chairman. Other chairmen for reunion events and a Western region co-chairman must be selected. You are invited to contact one of the class officers if you are willing to help in any way. — **E. David Howes, Jr.,** Secretary, Box 66 Carlisle, Mass. 01741; **Lou Mahoney,** 14 Danby Rd., Stoneham, Mass.; **Chuck Masison,** 76 Spellman Rd, Westwood, Mass. 02090

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The other day I saw the movie "Jaws," and it reminded me of our 20th Reunion. The scenes of the ferry, the beaches, the quaint town center, all stirred fond memories. But mainly, I remembered how the group attacked their roast beef dinner.

Now that **Marc Gross** is serving as a class secretary, you can count on alternate columns of rationality, and you should send some news to him. Two classmates did inform me of their activites. **Philip Molten** had a showing of photographs of Angel Island, presented by the Landmarks Society in Tiburon, Calif. . . . **Stanley Barriger** left New Hampshire for Rio de Janeiro to conduct a year's study of Brazilian Railway's repair practices. His address there is c/o Morrison-Knudsen Internacional de Engenheria, Rua Penheiro Machado, 22, Rio de Janeiro, Guanabara, Brazil.

For the reunion we conducted a class questionnaire — you probably recall throwing it out in mild annoyance last summer. In lieu of writing a book on the sociological implications, I have elected to summarize the results in this column. That way I can avoid all the TV interviews and bookstore ballyhoo that would be involved in the *Technology Review* trying to make me into the middle-aged male equivalent of Sally Quinn. The questionnaire had four parts. They were titled work, home and the family, my image of myself, and world view; but they meant: we want to know how much you make but we're afraid to ask, how tight is the ball and chain, how about sex, and are you as much a bigot as it says in *Time*?

The first part showed 7 per cent of those responding that identified themselves as always rich, 10 per cent as always poor, 34 per cent has having made it, and the rest as having tried. The average amount claimed that would be paid if a sober, unbiased appraisal were made of their work was $53,732 per annum. Forty-six per cent love every minute of their job, 31 per cent are tired of working, 6 per cent think they are treated miserably, and 18 per cent are treated miserably and are self-employed. In terms of rank, 17 per cent consider themselves captains of industry, education, gov't, etc., 34 per cent lieutenants, 25 per cent sergeants, 9 per cent company tools, 5 per cent shopkeepers, and 3 per cent wage slaves. Seven per cent are detached or isolated from commerce. Looking towards retirement, the intended age was 64½, which seems reasonable (some said never, one said 42). The anticipated retirement income was under $10K for 9 per cent, between $10K and $20K for 22 per cent, and over $20K for 29 per cent. Forty per cent had neither planned for it nor calculated it, which shows either a grasshopper-like attitude toward the future, or an anticipation of a rather large inheritance. In succeeding columns we shall continue this assault upon middle-age tensions and pretensions if you don't send news to the Co-secretaries: **Allan C. Schell,** 19 Wedgemere Ave., Winchester, Mass. 01890; **Marc S. Gross,** 3 Franklin Court, Ardsley, N.Y. 10502

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By now you will have received word from **Bill Grinker** that the 20th Reunion will be on campus during the first week of June. Contact Bill at American Used Computer, 712 Beacon St., Boston; the phone is 617-261-1100.

At the Alumni Officers' Conference **Ed Baker, Warren Briggs, Paul Cianci, Walt Frey, Ed Najjar,** and **Wendy Reis** were in attendance. Ed Baker has formed a new law firm — Gordon, Hurwitz, Butowsky, Baker, Weitzen and Shalov — on Park Avenue in N.Y.C. Walt Frey was back from London, where he had been working on lubricants for the Concorde in his new position at Mobil Oil.

Stanley Burg was elected Vice President of Staff Services of R.T.E. Corp. The Burgs and their two children (16 and 13) have been in Milwaukee for nine years. . . . **Stanley Hart** has been appointed Professor of Geochemistry at M.I.T. . . . Captain **Henry Herbig,** U.S.N., is commanding officer of the Naval R.O.T.C. unit at the University of Rochester. For the past four years he had been at Headquarters Materiel Command in Washington. Before that he had been in carrier-based antisubmarine duty, serving as commanding officer of antisubmarine squadron 39 and Intrepid's Air Group 56. The Herbigs have four children; the eldest is in his second year at the Naval Academy. . . . **Robert Kissner** writes that he founded Information Automation, Inc. in N.Y.C. back in 1972. The company supplies a computerized production-monitoring system for manufacturing plants. Robert, his wife, and two children live in New Jersey. . . . **Richard Kotelly** has been awarded a Bronze Medal by the Environmental Protection Agency for management of the Mass. Water Pollution Control Grant Program. . . . Last spring **John Morefield** spent six weeks in India and Sri Lanka as leader of the Rotary Foundation Group Study Exchange Program. . . . **Alex Rose** writes that he is with Pizzagalli Construction Co. of South Burlington, Vt., and is currently project manager of two sewage treatment plant contracts. . . . **John Stelling** just graduated from the AMP at Harvard Business School. — Cosecretaries: **Bruce B. Bredehoft,** P.O. Box 181, Dover, Mass. 02030; **Mrs. Lloyd Gilson,** 35 Partridge Rd., Lexington, Mass. 02173

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Just a few items this month . . . **Dick Conway** drops a note that he is serving as Chairman of the Executive Committee of A.S.C.E. Environmental Engineering Division. . . . **Jim Chorak** has been posthumously awarded the 1975 Bronze Beaver for recognition for his services to the M.I.T. Alumni Association. The citation reads as follows: "A volunteer emissary of the best of M.I.T. in whatever community he resided, he touched many others — fellow alumni, students and friends — with the spirit, pride and enthusiasm he shared for M.I.T. His contributions were cut short only by his tragic early death in 1974." . . . **Bob Palter** is now head of his own agency for National

Bob Palter, '57

"The alumni of Washington, D.C., have continued in 1974-75 a series of years of high accomplishment in area events, Educational Council, and Fund activities. Notable this year were the Iranian Embassy's generous reception and the intensive alumni participation as judges in several science fairs. The results are a new high in area membership and increased public awareness of an M.I.T. presence in the nation's capital — a program which stands among the very best of M.I.T.'s area volunteer activities." That's the text of a Presidential Citation delivered by Howard L. Richardson, '31 (right), President of the Alumni Association, to Kenneth F. Gordon, S.M. '60, in behalf of all Washington-area alumni, at the 1975 Alumni Officers' Conference.

Life Insurance Company of Vermont in the L.A. metropolitan area. Bob is a C.L.U. and has been with National Life of Vermont for eight years.

Steve Mason has been named executive vice president of the Mead Paperboard group. Steve will assist the corporate group vice president in the management of the Paperboard group which includes major operations in paperboard, corrugated shipping containers, packaging and specialty products made from recycled fibers. He will be located in Mead's Dayton headquarters. Steve joined Mead as an engineer in 1957. He worked in engineering and manufacturing assignments for six years at the company's white paper mill in Kingsport, Tenn. In 1963 Steve joined the staff of Mead Central Research in Chillicothe, later serving as a superintendent in Mead's Chillicothe paper mill. He was named general manager of Schoeller Technical Papers, a Mead affiliate, in 1970. In 1972 he was named product planning manager for the Mead Paper/Specialty division in South Lee, Mass., and was subsequently named vice president of marketing. He became director of Mead Central Research in 1973. . . . Lastly, **Ed Roberts** has been appointed to the David Sarnoff Professor of Management at M.I.T. — **Fred L. Morefield,** Secretary, 285 Riverside Dr., Apt. 6A, New York, N.Y. 10025

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As the fall season arrives here in Boston, heralding the not-too-distant December holidays, it seems like a time of renewal. Perhaps that's because I've had occasion to spend even more time at the old Institute, increasingly involved in its affairs and partaking of its activities for alumni. In so doing, I've been keeping in touch with many of our class members and am continually discovering what an interesting and fascinating group our class contains. So, resolve now to take one of those left-over greeting cards and write a few words on your latest fascinations.

During this year's Alumni Officers Conference, **Cole Bess** and I had a chance to talk and to find that he is still with New England Nuclear Corp. and living in beautiful downtown Newton. He has been keeping fit by jogging regularly for several years. Their two girls, Jane and Carolyn are growing like weeds, and the weeds are growing like a lawn but that's suburbia. If you're in Boston during the Bicentennial, Cole has invited everyone out for a drink and to say hello. . . . **Dan Holland** was also at the Conference and is busy establishing the Boston branch operations of the First National Bank of Chicago. His is also among the long list of firms awaiting the completion of the new John Hancock office tower, affectionately known as Pei's Plywood Palace by local wags. . . . Down Hartford, Conn. way, I talked with **Larry Boedeker** and found that he is still happily engaged in research at Pratt and Whitney's Research Labs, having avoided, somehow, that move into administrative paper-work that most of us get caught up in. . . . Whenever my car needs fixing, it's over to Hacker's Haven to see **Tom Magliozzi,** owner, chief mechanic, and all other titles held by those who start their own business. Tom recently returned from a trip to South America where he participated in teaching a mangement seminar to executives on organization and corporate planning.

While in Chicago recently, I visited with **Mel Copen,** who was recently enticed from Pittsburgh to join Gould, Inc. in their International Planning Department as its new Director. . . . **Jim Mahaffy** is also in Chicago and is President of Aluminum Mills, Inc., a firm which acquired the company Jim had started in 1972, Custom Metals Processing. Joyce and Jim are living in Elmhurst. . . . Last fall, **Toby Carlson** moved from Miami to join the faculty of meteorology at Penn State which, according to Toby, "requires an adjustment but so far all of us love it." He and his wife have continued their musical hobby of Renaissance instruments and have formed small ensembles in the State College community. Among the instruments they play are the viola da gamba, recorders, lutar, and shawn.

Fred Fisher tells us that "in addition to my consulting business, I am now Vice President of Boston Development Associates Construction Company, a new firm doing general construction on a condominium project in North Andover. It can still be said I pick the wrong time to do the wrong thing — or is it the right thing at the . . ." . . . In the San Francisco Bay area, **Andrew Chen** has been practicing medicine, specializing in E.N.T., since 1970. His wife also practices in the area of allergies. They have two children, ages seven and five. . . . **Ralph Johnston** is with Datel Systems in Canton, Mass., where he is a design engineer on power supplies, D/A and A/D video converters.

While strolling along the old Boston waterfront, currently in the throes of extensive renovation, I ran into **Marty O'Donnell.** He is with the law firm of Cesari and McKenna, located in a handsomely restored building called the Pilot House, overlooking the harbor. For you entrepreneurs and inventors, Marty continues to specialize in patent law. Marty and I also compared notes about the Massasoit building, another historic waterfront structure, formerly a fish processing plant, in which our company has offices. As many of you know, I and several others formed Technology Consulting Group, Inc., a management consulting firm, about two years ago. We specialize in corporate and divisional strategic planning, technology assessment and forecasting, market and product evaluation, and international business development. Our timing was superb, we've grown steadily in spite of the economic climate and prospects look reasonably bright for the future. Be sure to call when you're in town as we're near a lot of great restaurants, both new and old, and just a short hop away from the airport. — **Michael E. Brose,** Secretary, 30 Dartmouth St., Boston, Mass. 02116

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The class was well represented on Alumni Day last June with **Lowell Anderson, David Brahm, David Dayton, Frank Koppelman, Stephen Parkoff** and **Kenneth Wilson** and their wives participating in an updated view of the Institute.

Career notes include news of our Assistant Secretary **Bob Muh,** who was elected to the board of Louisiana-Pacific Resources, Inc., a real estate development concern in Palo Alto. . . . Many of you probably noted the important earthquake-related activities of **Lynn Sykes** in the *Time* magazine feature in September. Lynn heads the seismology group at the Lamont-Doherty Geological Observatory of Columbia University. . . . Recent appointments in industry included those of **Robert Flagg** to Vice President, Technical Operations of X-DEMEX Corp. in Dublin, Calif., which provides specialized explosive services to the construction industry, and **Paul Ekberg** as manager of the Chicago district for Republic Steel. Paul, who resides in Homewood, Ill., with his wife, Nancy, and their three children, recently completed an M.B.A. at the University of Chicago and joins Republic after varied experiences in

A Presidential Citation to the alumni of Colorado: "The alumni of Colorado, planning with an area-wide perspective a rich variety of programs ranging from a management seminar to a Pops Concert conducted by Arthur Fiedler at which undergraduates home on vacation attended with their invited guests, and including strong Educational Council and Fund organizations, have demonstrated a high standard of imagination, enthusiasm, and dedication in activities supporting the Association and the Institute. The result has been increasing participants together with heightened public awareness of M.I.T. and pride in being an alumnus." Here is Gordon W. Moore, '60 (left), accepting the tribute in behalf of his fellow Coloradans from Howard L. Richardson, '31, President of the Alumni Association, during the 1975 Alumni Officers' Conference.

the steel industry both in the United States and Europe. He will be responsible for the operation of Republic's Chicago steel plant which employs 6,000 people. . . . Moving to Washington with his wife, Harriette, and two sons was **Richard Weinstein,** who was selected as assistant executive officer to the associate administrator for center operations at N.A.S.A. headquarters. Richard started with N.A.S.A. after graduation as a physicist with the Langley Research Center and subsequently served on the space shuttle task group.

Other notes: **Walter Mallory** is serving as General Manager of Kodak Norge A/S in Oslo; from **Terry Gildea,** who with his wife, Marilyn, and their five children (3 boys, 2 girls) has moved from rural Colorado to San Francisco where Terry is Calculator Sales Manager for Latin America and Africa for Hewlett Packard; from **David Pawliger,** in the private practice of internal medicine, hematology and oncology; and **Bob Williamson,** who with his wife, Suzanne, and their two sons, is in Foxboro, Mass., where Bob is Manager, Man-Machine Interface Research for Foxboro Co.

David Moffett, who has served as the coordinator of the medical program on proton radiography at Argonne National Laboratory, was noted in many newspaper articles which highlighted the potential application of proton beams for the detection of "hidden" cancers.

On the publication scene, **Jeremy Glass** had an article on digital signal processing for radar in a Raytheon publication where he was listed as a member of the technical staff in the Radar Systems Laboratory of Raytheon's Equipment Division. . . . **Paul Weihrauch**'s work with Raytheon on the manufacture of rare earth-cobalt permanent magnets was noted in a local publication of the I.E.E.E. . . . A special note of congratulations to **Richard Holm,** professor of chemistry at Tech, and to **Kenneth Kellermann,** scientist at the National Radio Astronomy Observatory in Greenbank, who were among 84 distinguished scientists honored by their election to the National Academy of Sciences.

In response to an earlier column note from **Jim Snodgrass, Joe Pedlosky** sent a short history of his activities after finishing his doctoral work at Tech in meteorology. After teaching at the Institute and Imperial College in London, he joined the faculty at the University of Chicago where he is Professor of Geophysical Fluid Mechanics and has most recently lectured in Moscow and Leningrad at the Institutes of Oceanology. Joe, his wife, Holly, a photographer, and their daughter live near the university and he noted other classmates that he sometimes sees: **Stein Weissenberger** in California, **Bob Raymond** in Boston, his former roommate **Mort Rubin,** who is now teaching physics at the University of Maryland and **Jim Snodgrass'** former roommate, **Bob Manlove,** who is at Berkeley.

We close with a letter just received from our man in New York, **Phil Richardson,** who writes: "It is now almost October, the Alumni Officers Conference is over and our class secretary **Allan Bufferd** must by now be anxiously scanning his mail wondering whether these class notes will ever be written and mailed. Having looked over my calendar for the last year, I conclude that **Dick Sampson,** that stalwart bank and REIT stock analyst of Loomis Sayles wins first place for having seen more of me than any other member of the class of '59. For a while I thought Dick and I were playing musical chairs because of the frequency of which he dropped in on me in New York and I on him in Boston. . . . **Adul Pinsuvana** gets the long distance award. Charlotte and I had breakfast with Adul this spring in New York while he was passing through with one of his airplanes. Playing tennis must keep Adul fit, for he certainly looked in great shape. Adul called in again this summer when he was in New York for a few hours. We missed each other that day because I was in Boston having lunch with **Ed Safran,** our class agent. Ed is now running the short-term investment portfolio for Polaroid Corp. He must be doing well for my commercial paper salesman is always complaining that Ed gets nothing but the highest quality merchandise at the highest possible yields. . . . **Barry Weinberg** and I had lunch in late January. Barry is back living in Manhattan, has remarried and now has a small child in addition to running his own business.

"I've always enjoyed working on the M.I.T. telethons. This year I was surprised to get **Tip Noe**'s name and number on my list. I called his home in Bethesda, Md., and found out that Tip is alive and well and working for a federal agency. The other M.I.T. function I always enjoy is the A.O.C. in September. It gives me a chance to catch up on all the gossip. This year **Art Collias,** Katie and **Chuck Staples** and I spent Friday night drinking and talking. Seems Art is now in the swimming pool cleaning business which means six very early mornings for him a week. Besides that he acts as Brookline sales representative for Chuck Staples and friends' alarm business. With all the small business, Chuck, Art and everyone else around Tech is involved in, I was beginning to wonder if anything ever got done. During the cocktail hour on Saturday, Art brought over **Jim Hurley** and his recent bride, Annette. Jim has been living in Chicago and working as a sales representative for Blyth Eastman Dillon. He and Annette have now moved to Hinsdale for the duration. Good luck kids!

"During the summer, which Charlotte, the kids and I spent part of on Fire Island and part in Manhattan, we tried several times to get together with Norma and **Ed Talley.** We saw Ed and Norma in the spring in Manhattan for the big M.I.T. Club of New York event of the year — a super tour of and lunch on the *M.S. Sea Venture*, while she was docked at the new Hudson River passenger terminal. . . . Shortly after A.O.C., Jan and **Bob Hansen** and Charlotte and I made it out for dinner. Bob has recently been assigned responsibility for all the international business for Avon Products. He and Jan are living in Wilton, Conn., with their two daughters and one son. We had dinner at my favorite French restaurant, Le Veau d'Or, and spent hours catching up with our past. At lunch the next day with **Scott Latimer,** Scott told me he will be doing some international traveling for American Smelting and Refining. If this progression continues Adul Pinsuvana had better look out. Did anyone say the 20th reunion would be in Bangkok?

"I was reminded today that **Stephen Denker** is the new executive director of the New York M.I.T. Club (another reason for all '59ers to drop by the Club and say hello). Steve was previously living and working in Connecticut. He now commutes to the City and reports he is excited by his new job and surroundings. Write or call (212/952-1575) and tell me what's happening. See you all next year."

Let us hear from more of you and a happy new year from **Phil Richardson,** 180 Riverside Drive, N.Y., N.Y. 10024; **John Amrein,** 770 Greenwood Ave., Glencoe, Ill. 60022; **Bob Muh,** 907 Chantilly Rd., Los Angeles, Calif. 90024; **Adul Pinsuvana,** 49 Seri Rd., Seri Village, Hua Mark, Bangkok, Thailand; and myself, **Allan Bufferd,** 8 Whitney Rd., Newtonville, Mass. 02160

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We begin this month's class notes with the announcement that **Denis A. Blackett** has been appointed to the Massachusetts Port Authority Board of Directors. As President of Housing Innovations, Inc., Denis has directed the building and rehabilitation of over 1,000 units of low/moderate-income housing in the Boston area. Formerly an urban designer and planner with the Boston Redevelopment Authority, he has had extensive experience in land-use and transportation planning. Blackett is a native New Yorker and now lives in Newton, Mass., with his wife, Ruth.

C. Nicholas Pryor, Jr., has become Technical Director of the Naval Underwater Systems Center, having transferred from the White Oak Laboratory, Naval Surface Weapons Center at Silver Springs, Md. . . . **David Bushnell,** staff scientist at the Lockheed Palo Alto Research Laboratory, received the 1975 O.N.R./A.I.A.A Structural Mechanics Research Award for work on stress, buckling, and vibration. . . . **Cyril M. Pierce** has been named a Fellow of the American Society for Metals for distinguished contributions in the field of metals and materials. Dr. Pierce, who is Assistant Chief of the Manufacturing Technology Div. at the Air Force Materials Laboratory and is an adjunct professor at the University of Dayton, previously had been one of ten recipients of the Arthur S. Fleming Award, which honors outstanding federal employees. . . . Continuing in the structures and materials vein, **Richard C. Bradt** currently is Professor of Ceramic Science at Pennsylvania State University. Dick lives with his wife, Liz, and daughter, Meredith, on a farm near Bellefonte, Penn. (and he gets my special thanks for being the first to contact me directly with class note material). . . . Running a close second was **Bruce Layton,** who has just received an M.S. in Computer Science at Northeastern University. He is a software system engineer at Sanders Associates, having left the Air Force in 1974. Incidentally, Bruce was awarded the Bronze Star for meritorious service during a military tour in Southeast Asia.

A number of class members are active in alumni affairs. At the recent M.I.T. Alumni Officers Conference, **Ken Gordon** received an award for the program which he has engendered as president of the Washington, D.C., alumni Club. **Bob DeMichaels** and **Allan Morgan** received special citations for work on the 1975 Alumni Fund in Denver and Boston. **Marc Weiss, Dick Oeler, Noel Bartlett,** and **Cyril Pierce** chaired regional campaigns in New Orleans, Allentown, Cleveland, and Dayton. **Stephen Denker** is a regional representative for the Alumni Association.

Our Smilin' Jack-of-the-Month Award goes to **Larry Brock,** who verified Newton's Laws once again when the light plane which he was piloting experienced engine failure on takeoff. Larry was bashed up a bit in the final stages of the experiment, but we are glad to report that he is functioning normally again. Larry's normal functions include new product development at Hamilton-Standard, near his home in Burlington, Conn.

On a recent business trip, I spotted a distinctive eye-patch and knew right away that its wearer was **Jerry Woodall,** whom I had not seen in more than a decade. He is doing research on solar cell technology and applications at the I.B.M. Yorktown Heights, N.Y., Research Center, where there is renewed interest in the gallium arsenide solar cell which Jerry invented in the late '60s.

And now to summarize some earlier material (c. 1974) that failed to reach print. . . . **Burt S. Barnow** is on the economics faculty at the University of Pittsburgh. . . . Major **Bob DeMichaels** graduated from the Armed Forces Staff College at Norfolk, Va. . . . **Clay T. Whitehead** was appointed a research associate at the M.I.T. Center for International Studies and was named as a fellow at Harvard's John F. Kennedy School of Government. . . . **Lawrence R. Kravitz** earned the M.B.A. degree at Wayne State University. . . . **Michael Modell** is co-author of the book *Thermal Dynamics and Its Applications*. . . . **Sheila E. Widnall** was promoted to Professor of Aeronautics and Astronautics at M.I.T. and spent a sabbatical year with the Department of Transportation in Washington. . . . **Dick McDowell,** Director of Suffolk University's Center for State Management, was appointed Dean of the university's College of Business Administration.

Dick Levine, a consultant and adjunct Associate Professor at Fairleigh Dickinson University, has presented a four-day seminar on data communications as part of an A.D. Little Management Information Series. . . . **A. Thomas Guertin** was appointed Technical Manager for color pigments in the Pigments Div. of American Cyanamid Co. . . . **Christopher Ward** has become Assistant Treasurer for Kaiser Steel Corp., following 13 years engaged in operations research, engineering computing, and corporate planning. . . . **Kenneth Myers** was elected President of the Water Resources Association of the Delaware River Basin, a citizen environmental group. . . . **George Schnabel** reports that he is manager of facilities planning for the Rohm and Haas Co. . . . **Frank Tapparo** is working in program analysis and evaluation at the Department of Defense, and his wife, Mary, is working on power utilities environmental safeguards with the NUS Corp.

That just about wraps it up for this month, but first we would like to solicit opinions on two subjects. Each alumnus has received a new Alumni Association publication entitled "MIT76," which is intended to supplement alumni information on the M.I.T. scene. How do you like it? The second point: a regional breakdown of the Class of 1960 indicates that several areas of the country have sizable clusters of our classmates. The thought occurred that class members, particularly those who could not get back to Cambridge for the 15th reunion, might be interested in holding informal mini-reunion dinners throughout the country next June. If you like the idea, contact me directly, and we will see what we can get started. I have a regional list of the class, but you have to have the initiative (and the first respondent from a given area probably gets to be chairman of the local festivities). And while you are at it, keep the news of your activities coming my way. — **Robert F. Stengel,** Secretary, 152 Oxbow Rd., Wayland, Mass. 01778

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We have a reunion coming up in June. Already 15 years! I saw **Jerry Grossman** the other day (our fearless leader) and he promised to appoint someone as Reunion Chairman soon. It was his hope that we would plan a depression-style gathering this year. There always seems to be a recession on our anniversaries. Anyhow, to keep things cheap we will be based at the Institute again. Housing will be free on campus, and we will try to arrange accommodations at friends' houses. (That would make the food better and free.) We have lined up Castle Hill in Ipswich for a Sunday, June 6 clambake. That was very successful four years ago. So circle the weekend of June 5 and 6 next year and come back to Boston and the 'toot.

A long and interesting letter comes from **Pete Buttner** along with some interesting material from his office. He writes: "I have been in the Dean of Student Affairs Office now for over seven years as executive officer of the Freshman Advisory Council, and two years ago I was promoted to Associate Dean for Student Affairs. The job is relatively unique in terms of the mix of contact with students, faculty and staff, and in terms of my interests it suits me better than any other job I know of at the Institute. One of the more distinctive hallmarks of this office is the *Freshman Handbook*, which has evolved during my stay here, and for which during the last few years I have taken in increasing portion of the photographs." It is a remarkable and imposing tome of some 250 pages. I wonder how a poor freshman reacts to such an avalanche of facts, pictures, suggestions and little cards to cut out and send in. There's even a card if you want help getting from the airport! It really prepares the freshmen for the "drink from a fire hose." A companion volume Pete sent me describes each living group in detail so that people coming to R/O Week will be prepared. Pete goes on: "Marianne, Karl (ten), Lisa (eight), and I continue to enjoy Weston, where we have been living for the past six years. Marianne works for Education Development Center in Newton as Assistant Director on a project providing support to school systems as they attempt to implement the new Massachusetts laws and programs for children with learning disabilities.

"In case you haven't heard from **Shashi Gulhati** lately, he has just been promoted to full Professor in the department of Civil Engineering at the India Institute of Technology at New Delhi. Shashi brought his wife Rashmi to the States for a visit last year. We really enjoyed their stay with us. We did not meet their young son, Ashish, whom they left at home, and whom Shashi described as a bright, happy fellow, very inquisitive and quite unlike his father, thoroughly mischievous."

Another class member is rising in the ranks of management at M.I.T. That's **Bill Hecht,** Director of the Educational Council. Bill is taking a year off to be a Sloan Fellow for 1975-76, which is quite an honor. . . . **Donald Straffin** has also been working for M.I.T. He "recently worked on the Alumni 'Telethon' (gathering contributions) and discovered that there are dozens of grads living just a few miles away (in the Philadelphia area). Pat and I have four children. Recent years have seen us both getting involved in civic organizations. I just completed a year as President of the local Jaycees. This year it is P.T.A."

Another family with four children is headed by **Russell Zagrodzky.** His kids are all boys and they have all been living in Houston for the last eight years. He says

that "our" business ventures are a success and that he is President of a company he started six years ago. . . . **Stuart Lichtman** is also President of his own company. It's a Rockville, Md., consulting group that works for venture capitalists and other kinds of investors. He specializes in analyzing and "shaping-up" present and potential portfolio firms. . . . Another president in the class is **Nelson E. Stefany,** President of the Rohn and Hass subsidiary, Consolidated Biomedical Laboratories in Columbus, Ohio. C.B.L. is a diagnostic reference lab with emphasis on endocrinology. There are also a bunch of V.P.s in the class. **Phil Robinson** is Vice President, International Operations for Industrial Nucleonics and lives with his wife, Sally, and two girls in Upper Arlington, Ohio. **Richard Resch** is Executive Vice President of Krueger Metal Products of Green Bay, Wis. He's also on the Board of Directors. The Resch's have four children. Then there's **Richard Cummings,** Executive Vice President at Daystar Corp. He and his wife, Marie, and their three kids live in Reading, Mass.

There are plenty of other promotions to report. **James Barthold** is now an "associate" architect with the Kling Partnership in Philadelphia. . . . **Harry Rosenzweig** is Associate Professor of Mathematics at Western Maryland College in Westminster, Md. . . . **Bill Nieckarz** is also an Associate Professor of Chemistry at the University of Wisconsin at LaCrosse. He reports that he has two children: Greg, six, and Janey, two.

On television last night there was a short story about a new mode of commuter transportation in Boston: a boat going from the South Shore to downtown Boston. It's the brainchild of the State Secretary of Transportation: **Fred Salvucci.** Ah, but this morning things were not too rosy. The boat hit a rock on its return trip, incapacitating one of its propellers.

Bob Creasy sent a long note: "It is hard to believe our 15-year reunion is almost upon us. Rosalind, Robert (13), Laura (11), and I remain firmly planted in northern California. Ros is concentrating on edible ornamental horticulture, teaching adult education classes, lecturing, and writing a book. I get to eat some of the experiments! My research and development group at the I.B.M. Scientific Center in Palo Alto completed a high-performance interpreter, further enhanced by microcode of the A.P.L. language. I have been promoting its further use under VM/370, a time sharing system I conceived ten years ago. When not working and traveling, the family enjoys many outdoor experiences."

Hugh Fowler reports from Southern California where he works for Howard Hughes. He was in the East a couple of years ago to get an M.B.A. from Harvard. The Fowlers now include two girls: Julia (eight) and Serena (five). Also involved with Harvard is **Stan Abercrombie** who was a Loeb Fellow at the School of Design last year. . . . **Shyam Sharma** reports: "I am a professional engineer with Tippetts-Abbett-McCarthy-Stratton, Engineers and Architects in New York City. I recently supervised construction of the approximately $100 million Pan American Terminal expansion at J.F.K. airport. And I traveled to Saudi Arabia for the expansion of the Royal Saudi Air Force facilities in Riyadh and Jeddah. Currently I am designing drainage structures for the El Comandante race track in San Juan, Puerto Rico."

Finally a note from Golders Green, England and **Joel Gladstone,** who reports that he was appointed course leader for a new multidisciplinary course being introduced at the local Polytechnic. Joel said that his seven-month-old son, David, could expect a brother or sister in the next couple of months (when written last July).

Clear the decks for the reunion June 5 and write if you get work. — **Andrew Braun,** Secretary, 464 Heath St., Chestnut Hill, Mass. 02167

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George N. Krebs changed jobs from Assistant Professor of Physics at Manetta College in late July, and now is a senior member of the technical staff at Computer Services Corporation in Hyattsville, Md. He will be working on subcontract to Goddard Space Flight Center. . . . **Richard Reitman** is presently an engineering specialist at Aeronautronic-Ford. He is project manager for several satellite programs, and responsible for design, development and production of power conversion equipment. He, his wife Patty, four children, greyhound, mutt, and five cats are thriving in their environment. He is also extremely active in organizing A.A.U.'s swimming programs, including participation in their master's program. He is competing and doing very well (two miles workout each day). . . . **George C. Pedersen,** Pauline, and their four children have moved to Perrine, Fla., where they are in the throes of starting a new company manufacturing mist eliminators and tower packing for the C.P.I. Pollution Control Industries.

Kathy and **Philip Cassady** have finally bought a farm. They are located in Snoqualmie, Wash. (Route 1, Box 154), and although it is rather rainy, it is green and there's lots of room. Phil has joined Mathematical Sciences Northwest, Inc., as a principal research scientist. . . . **David Walter Rumsey** has now moved to Paris where he is an independent management consultant specializing in profit-improvement through expense reduction. . . . **W. Kirby Lockard** has written two books in the past year, *Design Drawing* and *Design Drawing Experiences.* These are currently being used in over 50 colleges and universities in the U.S. and Canada in schools of architecture, landscape architecture and interior design. . . . **Frank B. Sprow** is with Exxon U.S.A. Headquarters Supply Dept. in Houston and has been promoted to technical manager. . . . **Gary M. Stuart** has been appointed Assistant Treasurer of General Foods Corp., White Plains, N.Y. He is now living in Wilton, Conn., with his wife and four children. . . . **Arnold F. Stancell** is Manager, Petrochemicals and Plastics Div. of Mobil Oil Corp. in New York City and is the fifth person to participate in the current Black Executive Exchange Program's lecture series in applied engineering at South Carolina State College, Orangeburg. Dr. Stancell is married to Constance Newton. They reside in New Brunswick, N.J.

Ralph M. Scallion received the degree of Doctor of Medicine from the Case Western Reserve University School of Medicine on May 28, 1975. Dr. Scallion is a member of Alpha Omega Alpha honor medical society. . . . **Sherwin Greenblatt** founded and was the only employee of B.O.S.E. Corp. in 1964. He is now director of engineering and supervises all their technical activities. . . . Major **George F. Uhlig** is one of 22 Air Force scientists especially selected to judge the 1975 International Science and Engineering Fair held in Oklahoma City. He is assistant to both the deputy director and chief scientist of the Aerospace Research Laboratories at Wright-Patterson A.F.B., Ohio, where he maintains adequate fuel supplies for future Air Force needs. He also coordinates the working relationship between university and Air Force basic research efforts and facilities. His wife, Evelyn, is the daughter of Mr. and Mrs. Russell Gentry of Security, Colo. Major and Mrs. Uhlig have two children, Jean and Becky. . . . **Lawrence H. Pitts** has just completed his neurosurgery residency at the University of California in San Francisco and has joined the faculty as Assistant Professor of Neurosurgery. After an initial six months at San Francisco General Hospital, he will begin an eight-month Van Wagenen Fellowship with the Department of Neurosurgery at the University of Glasgow, including additional side trips to a number of neurosurgery centers in Europe. Mary and their two children will join him. He recently saw **George Meyer,** who is completing a gastroenterology fellowship with the Air Force and is now at Travis Air Force Base near San Francisco. George and Lynn have two children and will probably leave the Bay Area in about one year. . . . **T. J. Lageman** was visiting George with his wife and two children. He is currently working with a large commercial laundry and is developing a water recycling process for use in certain industrial processes.

Brandon Qualls has just accepted an appointment as Assistant Professor of Psychiatry with Brown University in Providence. He and his wife, Jane, just left the Bay Area after five years. . . . **Max Snodderly** was married last summer and he and Dolores live in the Boston area. Max is still on the staff at the Retina Foundation in Boston and on the faculty at Northeastern University. . . . **Joe Perkell,** Chris, and their daughter moved to Hanover, N.H., where Chris has joined the Dartmouth faculty as a classics professor. Joe commutes to the Institute and is still doing research in the biochemics of speech with the Linguistics and Electrical Engineering Departments. . . . **Murray Sachs** is Associate Professor of Physiology and Biomedical Engineering, continuing to work in the basic physiology of the auditory system at Johns Hopkins University. . . . **Marshall R. Singer** is currently Professor of International and Intercultural Affairs, Graduate School of Public and International Affairs at the University of Pittsburgh.

Richard A. Oman, '55, was kind enough to inform us that **Alexander Bogan, Jr.,** was killed on May 16, 1975, as he was being driven home from a bachelor party in honor of his forthcoming wedding. The car in which they were riding was hit by a large tar truck. His brother-in-law and a colleague from the Grumman Research Department were also killed in the car. He had received M.S. and Ph.D. degrees in physics from Case after graduating from M.I.T. and did a year of post-doctoral work at the University of Virginia. He joined Grumman permanently in 1968 where he worked on gas-surface interactions, solid state physics

If Julio Silva, South American architect, had never gone to Upper Volta, the world might never have seen the beauty of the West African tribal culture – now colorfully represented in Upper Volta's postage stamps.

Silva Spreads Beauty of Upper Volta Worldwide

A series of nine stamps depicting everyday scenes and costumes of the West African tribal culture of Upper Volta are facsimiles of sketches by Julio Silva, M. Arch. '62.

When Silva went to Upper Volta in 1967 as a United Nations advisor on low-cost housing, he was immediately impressed by the diversity of customs, the fold art and the beauty of the native housing. Reporting that "every house is a work of art," Silva quickly dismissed the idea of advising major change in the basic construction of the native mud huts with adobe walls, rounded corners, sunny courts and cone-shaped roofs of hand-woven thatch. Rather than replacing the adobe huts with look-alike prefabricated structures, he suggested improving these unique homes with better sanitation, lighting and ventilation.

Traveling through the underdeveloped districts of the three Volta rivers in his small car — complete with an M.I.T. decal in the rear window — Silva would meet with members of many of Upper Volta's tribes. After observing their life style and learning the values of their culture, Silva suggested architectural improvements while developing rapport with the tribesmen.

When breaks in his busy work schedule allowed, Silva would return to his headquarters in the capital city of Ouagadougou and would sit in the open-air cafes, sketching the busy life that surrounded him. Africans in gaily colored costumes making their way through open markets in streets lined with sheep, camels and bicycles proved exciting subject matter for the Uruguayan architect.

Enthralled with Silva's sketching and encouraged by Silva many young Upper Voltans began imitating him and soon Silva's followers were sufficiently accomplished to sell many of their sketches to tourists.

This art, which reflected African rather than French values, received nation-wide and eventually world recognition for both Silva and Upper Volta. After an exhibit in the French Embassy in Ouagadougou, Silva's paintings were sent to New York, where they were shown at the U.N. headquarters. One painting was retained by the U.N. and now hangs in the David Owens Library.

Since his successes in Upper Volta, Silva was transferred by the U.N. to Togoland for a short-term project and then, in 1974, to the Ivory Coast, where he is a U.N. project manager, supervising the construction of public facilities for rural communities and advising the Minister of Planning on construction.

Julio Silva has decided to make West Africa his permanent home. Having grown to think of the migrant tribesmen of Western Africa as "his people," he will continue to work at bridging the gap between the modern cities of Africa and the rural communities — while still preserving and promoting the West African culture. — by Ellen Hoffman

and vibrational excitation in gases. — **Gerald L. Katell,** Secretary, Parking Structures International, 250 E. First St., Los Angeles, Calif. 90012

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Short column this month. Just a few notes from you and some personal news.

Bob Petrich was (last June) in the process of moving his family (wife Pat, and children: Robbie, nine, Michael, four, Stephanie, two) to Cannes, France, where he is taking over responsibility for the Plastics Laboratory of Rohm and Haas European Laboratories. Bonne chance! . . . Another classmate on the move is **Steve Zilles.** Last November (1974) Steve transferred to the I.B.M. Research Laboratory in San Jose, Calif. He writes that the whole family is happy to be in the land of warmth and sunshine. His older son started kindergarten this fall and his younger is in nursery school. . . . **Howard Leibowitz** is currently working as a manager in Corning Glass Works' Machine Technology Department. He resides at R.D. 1, Big Flats, N.Y. 14814, with his wife, Sally, and their three daughters aged eight, nine, and ten. . . . **Dan Greenwald** finished a residency in psychiatry last June and is now a staff psychiatrist at the Carrier Clinic in Belle Meade, N.J. Dan also has a private practice. . . . A press release informs us that **Harvey Picker** has been promoted to the rank of associate professor of physics at Trinity College in Hartford, Conn. Harvey went to Trinity as an assistant professor in 1971. Prior to this he was a research physicist at Carnegie Institute of Technology, an N.S.F. Postdoctoral Fellow and instructor at Princeton University and a research associate at the University of Maryland.

In the personal news column — two promotions. My wife, Barbara, has been promoted to the position of Assistant Dean of Students at the University of California at Irvine. I have also received a promotion at Nucleonic Data Systems, where I have been for the last four years. I am now Director of Engineering, with responsibility for all technical activities within the company. This may strike you as an odd occupation for someone with a background in nuclear physics — over the last few months it has struck me the same way. As **Jack Solomon** noted in a recent card ". . . last year I couldn't spell ingineer and now I are one." That was a bad joke at the time and I guess it's a bad joke now. Keep those cards and letters coming in. Merry Christmas, Happy Hannukah, bonne année. — **Mike Bertin,** Secretary, 18022 Gillman St., Irvine, Calif. 92664

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Hello, classmates! You'll see the change of address at the end of this column, but, nevertheless, please take note: we have moved.

First the errata. Apologies to the **Bob Gray** family and particularly his son Timmy, whom we mistakenly and regrettably identified as Tina in last August's Issue.

Two class heroes this month. First **Edward W. R. Casper.** He and his wife Gale (both Virgo) have a new and welcome addition to their household, Heather Evelyn, born on August 20, 1975, a Leo with Virgo leanings. Ed has attained a purple belt in karate, and he quipped ". . . the color of the belt roughly correlating with the colors of the bruises gained during work-outs." He has focused his musical attentions on the accordion, now owns an electrified Sonola with Ampeg amplifier, and has performed at local fairs and crafts festivals, in addition to entertaining baby Heather with practice sessions.

Our second class hero is **G. Michael Sullivan,** who had so much to catch us up on that he wrote the news clip for me. He writes: "Since '64 have been living mostly in the San Francisco Bay area enjoying a good life. Am now working for Hewlett-Packard as a product manager for the HP-21, HP-35, and HP-45 handheld calculators. Previously spent 2½ years consulting to a variety of small businesses right after graduation from Stanford Business School in '71. While lucrative enough, consulting on my own was only a little less demanding than Army Signal O.C.S., Jump School, getting married to a German girl in Florida, and one year in Vietnam. Before all that I spent two years as a research engineer for N.A.S.A. Finally, please say hello to those friends I haven't seen for so long. My present address is 1430 Braddale Ave., Los Altos, Calif. 94022."

On the class notes side, we have learned that **Martin C. Jischke** is one of 14 White House Fellows selected for this year. . . . **Margaret L. A. MacVicar,** Associate Professor of Physics at M.I.T., has been elected to the Board of Directors of the Sprague Electric Co., the first woman director of the multinational electronic components manufacturer. Dr. MacVicar is a trustee of the Carnegie Foundation for the Advancement of Teaching and is a member of the American Physics Society, the American Association for the Advancement of Science, the American Vacuum Society, the American Society for Metals, the Society for Women Engineers, American Women in Science, and Women in Science and Engineering. Additionally, she was the Marie Curie Fellow in Physics at the Cavendish Laboratory of the University of Cambridge (England) in 1968-1969. . . . **Douglas W. McCowan** earned the degree of Doctor of Philosophy in Geophysics from the Pennsylvania State University this past June.

Last (but not least I hope) is our story. After more than eight years with R.C.A., in which I was involved in nearly all aspects of second-and third-generation automatic test equipment (A.T.E.), it seemed time for a change. The right opportunity came along in the Washington, D.C. area and we scooped it up (job selection:I; interstate moves: WE). In my new position, the task is to provide consultant engineering services to the navy in A.T.E. and A.T.E.-related areas. I've been at it since August and have loved every minute of it so far. If you're in the D.C. area, we're only 30 minutes from Washington National Airport; please call and come over to visit.

That's the news for now. Please keep writing and keep your contributions going to M.I.T. — **Steve Schlosser,** Secretary, 12401 Bobbink Ct., Potomac, Md., 20854

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It is a gorgeous fall day as I write; hope the weather is as nice when this reaches you. The mail bag has been light, but fortunately news has arrived on the backs of Alumni Fund envelopes. **Bob Menzies** recently spent six months teaching at Chalmers University of Technology in Gothenburg, Sweden; he is now at Cal Tech's Jet Propulsion Lab, developing laser instrumentation for atmospheric monitoring. . . . **Frank Gerstle** has been promoted to Supervisor of Composite Materials Development at Sandia Laboratories; the Gerstles have two boys, four and one years old. . . . **Bill Samuels** is in Brasil, where he has founded MIND do Brasil Servicos, an education and training company of which he is president. . . . **Barry Smernoff** received a Ph.D. from Brandeis and has spent the past five years as a "futurologist" at the Hudson Institute. Barry and Barbara have two children, Michelle, seven, and Jeffrey, four, and Barbara is running a dance studio. . . . **Peter Brown** is with Boeing, acting as project engineer for the development of their Advanced Concept Train, a new venture in mass transit. Jeanne and **George McQuilken** live in Bedford Village, N.Y., where their three children are in school; George is editor of the I.B.M. Systems Journal while Jeanne has returned to school: Urban Studies at S.U.N.Y. . . . Cathy and **Gary Welch** have moved from Houston to the San Francisco area, where Gary is with Shell Chemical.

John Leide received a Ph.D. from Rutgers this past June (this from the Rutgers News Service — John will have to write and tell us the field). . . . **John Matton,** who has been with Combustion Engineering since 1967, was recently promoted to regional product manager-nuclear in the sales and marketing department of C.E. Power Systems. The Mattons will be living in the Chicago area. . . . **Bruce Fauman** is now teaching the School of Management at the University of Rochester. . . . Linda and **Jim Steele** and their daughter Laura are living in Framingham; Jim is with Digilab. . . . **Jesse Lipcon,** the old coxswain, is to marry Lynne Johnson on October 11. Jesse gave us word of **Mike Oppenheimer,** the last '65 bachelor of the Z.B.T. class, who was last heard from touring France. That's it for now. Please write! — **Edward P. Hoffer,** Secretary, 12 Upland Rd, Wellesley, Mass. 02181

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Happy Holiday Season to All. **Kevin Kinsella** has been appointed one of four district officers for M.I.T.'s five-year $225 million Leadership Campaign. As district officer for the Western States, Kevin will work with area leaders in soliciting funds and support from M.I.T. alumni, friends, foundations and corporations. . . . **Dick Schulze** is serving at Wright-Patterson A.F.B., Ohio, as a trial attorney for the U.S.A.F. on contracts cases before the Armed Services Board of Contract Appeals. Captain Schulze, a judge advocate, received his law degree from the University of Chicago in 1970. He and Anita have their first child, Elaine Maryann, born April 8, 1975. Elaine has her father's huge appetite and is doing very well. . . . **Anthony Sinskey,** associate professor of nutrition and food science at M.I.T., has been awarded the 1975 Samuel Cate Prescott Award by the Institute of Food Technologists for his research on the impact of

food processing on microbial metabolisms. The award carries with it a $1,000 honorarium. . . . **Paul Tarantino** and Anne McDonnell were married July 28, 1973. . . . Since April of 1971 **Michael Ahern** has been employed in the Irish Patents Office as a patent examiner. . . . **Bob Rosenberger** has joined Technomic Research Associates in Chicago as a marketing consultant. Stephanie and Bob have two West Highland White Terriers as surrogate children. Bob collects and restores old slot machines and is interested in communicating with anyone having the same interest. . . . Having moved five times in six years, Captain **David Garbin** is enjoying growing roots at Defense Communications Engineering Center in Reston, Va.

Brad Cross writes: "Receiving a job offer these days can accomplish miracles. Although I hadn't started writing my thesis when I received an offer from the International Atomic Energy Agency, I was on my way within two months, with a Ph.D. in Physical Biochemistry from University of California in hand. After stopping in Boston to visit Sigrid and Gardiner Gay, '68, John Klensin, '66, and the Alpha Phi Omega office, we left for a two-year contract with I.A.E.A. in my wife's hometown of Vienna, where I am head of the Computer Section's Scientific and Technical Applications Group. Turnabout being fair play, now I'm working while my wife gets her Ph.D. in Marine Biology. My advice to anyone who visits: be sure to spend one evening in a small non-tourist heuriger (close to a wine celler) — it's well worth the trouble to find one." . . . Having completed four years of training at St. Louis Children's Hospital, **Paul Goldstein** is practicing pediatrics in Chicago. . . . **Philip Galiger** works at Thomte-Roper in Boston and lives on an old farm in Franklin with his family and three black sheep. . . . **Bob Steele** performs energy and environmental research at Stanford Research Institute. He and Angela live in Mountain View, Calif., where Angela teaches English. . . . **Loughrey Kuhn,** Coralee Stevens Kuhn, '70, and their two children have moved into an old Maryland farmhouse (circa 1820) near Washington, D.C. The trees are tall and the wind blows fresh over the fields. . . . Ellen and **Jeffrey Shapiro** moved into a new house in Sharon, Mass. last year and are awaiting the January birth of their second child. Jeff is an associate professor in electrical engineering at M.I.T. He looks forward to seeing everyone at the Tenth Reunion. . . . **Hiroshi Iino** returned to Teijin, Ltd. in Japan in 1967 and was in charge of developing a polyester tire yarn and constructing and managing its manufacturing plant. He is now with Nippon E.V.R. Ltd., an E.V.R. (Electronic Video Recording) cassette processing company. . . . **Harold Iuzzolino** works for the University of New Mexico's Civil Engineering Research Facility as both a research scientist and supervisor of C.E.R.F.'s computer support group. Since the group was recently split into two groups, Harold is hoping that the rate at which his hair is thinning will decrease. He and **Carlyn (Voss)** were counselors at the Albuquerque Billy Graham Crusade last March, and in April their second child, Mark, was born. Carlyn recently tailored a red suit for Harold, prompting him to dump his old funeral gray suits. . . . Following graduation **Victor Bermudez** was a graduate student for two years in the Department of Chemistry at Princeton, and he later served for three years as a naval officer at Naval Research Laboratory, Washington, D.C. He returned to Princeton in 1972 to complete the work on his Ph.D. in Physics and Physical Chemistry. Victor is now writing his thesis and working full-time at Naval Research Laboratory. — **Jim Swanson,** Secretary, 669 Glen Rd., Danville, Calif. 94526

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It will be Season's Greetings time when you read this and we would like to extend our hopes to everyone for a happy and healthy New Year. I hope the country will be able to survive the bicentennial. First we'll start off with the milestones. **John Niles** married Elizabeth Swanson on May 31. They met several years ago when both worked in Brunswick, Maine. After a week's honeymoon in the Yucatan, they returned to D.C. where John works for the city government in a group working on projects to improve the quality and efficiency of city services such as housing code enforcement and street maintenance. Libby is a special education professional who will be developing a curriculum this year to serve learning disabled high school students in Fairfax County, Va., Public Schools. . . . **John Dehne** and his wife, Carol, had a daughter, Christine Laura, their second child in March. John has managed to infiltrate the U.S. portion of a N.A.T.O. group in image processing, thus setting himself up for a government-paid boondoggle to Paris and the Riviera in July. . . . From Versailles, Ky., Nancy and **Tom Griswold** write that they adopted two boys, Ronnie, 12, and Scott, 10, in February. They are living in a large, vintage 1921 house which is one of the newer ones in the area. Their household also includes three dogs and two kittens. Tom has mixed feelings about his job as a project manager at Spindletop Research, Inc. in Lexington, Ky., and he's still "plinking away" at a doctorate at the University of Kentucky.

The University of Vermont has awarded **Dennis Artman** a doctorate in chemistry. . . . **Steven Finn** "finally" received an Sc.D. in Course VI in February and now works for Codex in Newton. He reports being "sorry to leave" after almost ten years. . . . Two faculty notes this month: **Yue-Ying Lau** has joined the math department at M.I.T. and **Fred Orthlieb** has joined the engineering department of Swarthmore. . . . **Robin McGuire** graduated from the 'tute in September 1974 and moved to Colorado with his wife and dog. He's now the "token engineer" of the U.S. Geological Survey there. . . . After receiving a Ph.D. in math from Berkeley in 1972, **Dan Asimov** spent a year in France prior to joining the math faculty at the University of Minnesota (Minneapolis). He is now on leave at the Institute for Advanced Study. . . . **Mark Helfand** received a Ph.D. in applied math from Cornell in 1974 and is a postdoc at the Goddard Institute for Space Studies in New York City. His wife, the former Lynn Philip, has a B.S. from C.C.N.Y., and an M.S. from Cornell and is presently teaching at C.U.N.Y. His research is in meteorology and involves frequent interaction with M.I.T. faculty. . . . **Jim Kirtley** is back at M.I.T. after spending a year with G.E. learning to build large steam-turbine generators. He adds, "Quite a bit different from academia, but just about as much fun." . . . **Curtis Blaine** has started a management consulting firm called "System One Consultants," based in Chicago. It specializes in software development, general computer consulting, and operations research. . . . **Andy Friedland** is an associate at the law firm of Gasperini and Savage. He and his wife, Linda, also an attorney, live in New York City and would like to hear from people in town.

Off in Tyner, Ky., **Tom Wilson** is now President of Phoenix Products, Inc., a manufacturer of sporting goods. . . . Nearby, I think, **Howard Wagner** has started part-time law studies at the Salmon P. Chase College of Law of Northern Kentucky State College in Covington. . . . **Carol Geisler** is at N.Y.U. where she's working on her thesis for a Ph.D. in experimental psychology in the area of cognitive psychology and memory. She also has begun training in psychotherapy. . . . **Lissy Quinlan** has a postdoc at Harvard with a joint appointment as a fellow of the Radcliffe Institute and a fellow in environmental engineering. . . . From Cleveland we hear that **Arshad Sheikh** is working for Sohio as a lead analyst in the refining systems department. . . . **Walt Oney** is still working as a computer programmer but is thinking about other things as he goes to law school at night. His first, and probably last, paper has been published in the *J.A.C.M.* . . . Last May, **Gunnar Jacobsen** finished an eight-and-a-half-month management development program at the North European Management Institute in Oslo. The 21 students in the program came from eight countries while the faculty was mainly from the U.S. . . . **Darryl Pomicter,** Charlene, and their sons, Edward and Benjamin, are still living on Beacon Hill. Darryl is Assistant to the President of American Science and Engineering in Cambridge. . . . During the summer of 1974 **Michael Knudsen** joined the staff of Bell Labs. His first child, Daniel Jeremy, was born on September 14, 1974.

From South America, **Enrique Tejera-Rodriguez** reports that he is now executive vice president of Entepar C.A. which designs and manufactures calculators and microcomputers. He is continuing research in the field of bioengineering and teaches at Universidad Simon Bolivar. His family has grown and now includes two daughters, Maria Valentina and Maria Carolina. . . . **Robert E. Lee** has joined B. T. Consultants, of Bankers Trust Co. in New York as a financial consultant in corporate planning advisory services. . . . Louise ('70) and **Jerry Grochow** have moved to D.C. now that Louise has finished at Johns Hopkins and is an intern at Georgetown University Hospital. He reports that all is well with **Mike Tashker** and **Carl Rodoni** in California. . . . **Leonard Mausner** has joined the staff of Los Alamos after teaching at Princeton. . . . Finally, **John Yue** received the Skylab Medal for Exceptional Scientific Achievement from N.A.S.A. for his work on the analysis of space-grown semiconductor crystals. He works for T.I. in Dallas where he is now studying silicon materials in an effort to improve semiconductor device performance and yields. . . . See you next month. — **Gail** and **Mike Marcus,** Secretaries, 2207 Reddfield Dr., Falls Church, Va. 22043

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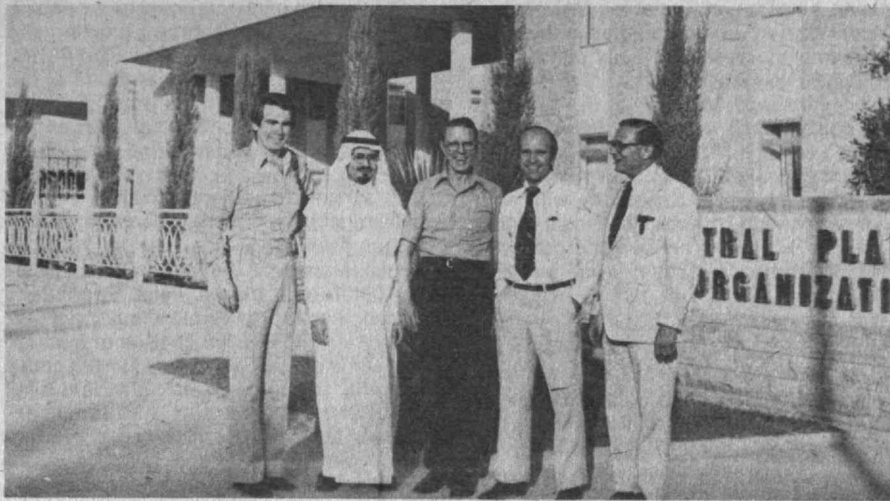
Well sports fans — with nothing to do be-



An unusual picture of an unusual event: an M.I.T. "reunion" in Riyadh, Saudi Arabia, when five members of the Institute community chanced to be together on business there late last spring. From left to right they are Richard O. Bond, S.M.'70, of the management consulting firm of Cresap, McCormick and Paget, Inc., New York; Mohammed A. Bakr, '71, of Saudi Arabia's Central Planning Organization; Everett E. Hagen, Senior Research Associate in M.I.T.'s Center for International Studies who is a member of the Central Planning Organization's Advisory Board; Leslie M. Boring, Jr., '64, a marketing officer for the First National City Bank of New York stationed in Riyadh; and Richard S. Kaynor, S.M.'54, who was then a Senior Consultant to the First National City Bank, Riyadh. The picture was made in front of Mr. Bakr's office.

cause the N.F.L. is on strike, it appears to be time to write another stirring account of the '69 adventures. Many classmates contributed to the 1974-75 Alumni Fund drive. I extend my thanks along with those of the class agent and Mother Institute, who will hopefully put the money to good use.

Carl M. Abramson writes that he is a sales engineer for Brunswick Corp., Technical Products Business Group. They sell static-control yarn to the carpet industry. Carl also informed us that **Bill Box** is with the Dade Div. of American Hospital Supply in Miami, Fla., and that Tom Bales, '70, is with Cordis, Inc. in Miami.

John R. Bates, Ph.D. '69, writes that he was an Assistant Professor of Meteorology at the University of Illinois at Champaign-Urbana in '72-'73, and apparently returned there in September of 1973. John married Anne Wilson Mitchell at Wayne, Penn., in August, 1973.

Michael L. Bennett planned to move to St. Louis sometime in the summer of 1975. Mike's wife Diane started anthropology graduate school this autumn. . . . **Paul W. Chin, Jr.,** received his Ph.D. from M.I.T. in March, 1974, in the field of control systems science. He is now on the corporate staff of Shell Oil Co. and is "learning lots about the business operation of a very large corporation."

The following class members received the degree of Doctor of Medicine from the Case Western Reserve University School of Medicine on May 28, 1975: **Shelley Fleet** (Mrs. Edward S. Ackerman), **Bruce M. Cohen,** and **Peter Q. Harris.**

Shelley is scheduled for graduate training in anesthesiology at the University Hospitals in Cleveland. Bruce is going into psychiatry at McLean Hospital (Massachusetts General) in Belmont, Mass. Peter will be in psychiatry at Dartmouth Affiliated Hospitals in Hanover, N.H.

Ted Crowley just left the Air Force after four years as a pilot. He's now in Princeton, N.J., doing software design for R.C.A.'s Astro-Electronics Div. . . . Evelyn B. Hall of New York married **Richard W. Dorman** in April, 1974. Richard is Director of European Tour Products for the American Express Co.'s Travel Div. and is in charge of all marketing and planning for Europe. . . . According to "D-Notes," which is apparently a publication of the Charles Stark Draper Laboratories, **Mike Blitch** (a.k.a. "River Rat") completed the 1975 Boston Marathon in three hours and 20 minutes. Well done. Mike is in Draper's Guidance and Navigation Analysis Div.

According to a news release from the American Association for the Advancement of Science, **George J. Flynn,** a physics doctoral candidate at Washington University, has been selected to participate in the Mass Media Intern Program sponsored by A.A.A.S. George was scheduled to work with *The Charlotte Observer* for ten weeks beginning in mid-June. . . . **Geoffrey Hallock,** who when last seen was running on the cross-country team, has been accepted as a surgical intern at the Mary Hitchcock Memorial Hospital, Hanover, N.H., and the Veterans Administration Hospital, White River Junction, Vt. These hospitals are affiliated with the Dartmouth Medical School.

William R. Harris has been ordered by the Navy to the Naval Academy Dept. of Naval Systems Engineering as an instructor of Naval Architecture and Marine Engineering. . . . Recently discovered on the Technical Staff of the Computer Systems Div. of Bolt, Beranek and Newman in Cambridge, was **Steven E. Jeske.**

According to a publication that looks strangely like *Tech Talk* or one of its successors, **Timothy L. Johnson** was recently promoted from Assistant to Associate Professor in Electrical Engineering and Computer Science at a well-known technological institution in Cambridge, Mass. Tim is researching applications of electrical engineering to biomedical systems and optimal control theory. . . . **Henry I. Levine** will be a first-year resident in Pediatrics at Beth Israel Medical Center, New York City, commencing on July 1, 1975.

Eugene Franklin Mallove received a S.D. in Environmental Health Sciences from Harvard, in June. Eugene's thesis was entitled "Aerosol Measurement by Combined Light Scattering and Centrifugation."

Kendall C. Marr completed his residency in internal medicine in June, 1975. Kendall's internship was at Cleveland Metropolitan General Hospital; in June he began work as a clinical associate at the National Cancer Institute in Bethesda, Md. Kendall plans to use his engineering and computer background in the analysis of different cancer therapy programs. He expects to do postdoctoral work in cardiology.

Tim Merrill returned to San Francisco upon graduation and worked in biological research instrumentation for three and one-half years. He then did some international traveling for 18 months and is now back at Stanford. . . . **Barry D. Milder** is a second-year resident in ophthalmology at the University of Florida. He is also the proud father of a 14-month-old daughter, Rebecca.

Eric R. Pearson writes that he was at the Knolls Atomic Power Lab for three and one-half years as an engineer. He then moved to manager of quality control at Cast Technology in Schenectady and is now Plant Manager at Esquire Novelty Corp. in Amsterdam, N.Y.

Richard A. Pinnock earned his M.S. in Nuclear Engineering from M.I.T. this spring and is now on his way to Chicago where he will work as a nuclear engineer for Commonwealth Edison. . . . **Ilt Hans Polzer** writes that he married Audrey L. Boulden of Cecilton, Md., on April 12, 1975. He is now a system engineer for two PDP 11/45 machines and is the only programmer. All computer hackers are invited to revel in the thought of 248K words of core and 350 million bytes of disk storage all to yourself.

Sheila and **Farrell Powsner** announce the birth of their son, Steven Robert, on May 20, 1975. . . . **Jeremy K. Raines** writes that his firm just completed its first government contract: the design of a quasi-isotropic VHF antenna array for the International Ultraviolet Explorer satellite. Jerry also taught a course in Computerized Antenna Analysis as part of the George Washington University's Continuing Engineering Education Program.

Geoffrey (Geoff) Russell spent three years of nomadic life with Esso Research and Engineering Co. in New Jersey, Venezuela, and Louisiana. He is now in the Ph.D. program in Material Science and Engineering at the University of Utah, and expects to earn the degree in June, 1976. . . . **Ron Skellenger** would like to hear from the brothers of Sig. Ep. at Post Office Box 433, Lagunitas, Calif. 94938.

George C. Slusher, Captain, U.S.A.F., has arrived for duty at Luke A.F.B. as a mechanical engineer. George had been at Wright-Patterson A.F.B., Ohio, and is now a member of the Tactical Air Command. . . . **N.I. Salas** is presently employed as operations supervisor in the hydrodesulfurization Division of the Lago Oil and Transport Co., Ltd. (an Exxon subsidiary). . . . **Richard**

Smith spent three years in Beantown after graduation, the last two years in Palo Alto, Calif., and is entering the Harvard M.B.A. program this autumn.

Stanley Terman is a Clinical Pharmacology Fellow of the Eli Lilly Co. and a Psychiatry Resident at Indiana University. . . . **Donald Vawter** was anticipating the receipt of his Ph.D. in bioengineering in August, 1975. Donald indicates that there is no job in sight. Other M.I.T. grads in San Diego include Lee Kamerdiner, '68, Rocky Swenson, '68, Richard Mushotsky, '68, Larry Icerman, '67, and Bill Fincke, '68. . . . **David Q. Wells, Jr.** is now an Actuarial Associate at Travelers Insurance Co. in Hartford, Conn. He works with F. Tom Gumersol, '66, and Donald MacKillop, '52.

It's difficult to comprehend but the pile of letters has mysteriously moved from one side of my typewriter to the other. Merry Christmas, Happy New Year, and best wishes for any other holidays which occur until my next column. — **Peter Peckarsky,** Secretary, 950 25th St., N.W., Washington, D.C. 20037

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News from our class shows how varied are the interests of our classmates. **Peter Fr. Strom** received his M.S. from Rutgers; unfortunately, they didn't bother to tell me in what. . . . **Alan J. Grodzinsky** an assistant professor at the 'Tute in electrical engineering and computer science was appointed Esther and Harold E. Edgerton Assistant Professor. Alan's research has been mainly on transduction properties of biological tissue, collagen, and other membrane structures, with application to implantable medical assist devices. . . . From beyond the world of academia, **Walter J. Daub** writes, "I'm recuperating from a broken clavicle and other injuries I got on a bad fall from a bull during last June's Tarrant County Rodeo championships. Hope to be back in the saddle soon." . . . **Paul D. Palmer, Jr.,** is another one of the more athletic members of our class. He had broken ground on his 50-ft. ketch *Lau Eng* as of July 4, 1973, has now finished the hull and decks, and hopes to complete the cabin in time for launch next spring.

Michael N. Hayes is now assigned to the *U.S.S. Kitty Hawk*. . . . **Howard Jay Siegel** writes that he and **Leah** are at Princeton University working toward their Ph.D.'s in computer science. . . . **Paul D. Greenfield** who spends his spare time playing bridge and rooting the Yankees to a pennant (not this year, though) is employed as a financial analyst for the Fiber Division of the Allied Chemical Company in Times Square. Brother, Alan, '69, is living in an apartment on the upper East Side of Manhattan. . . . **Peter Stoll** has been busy designing integrated circuits for Intel Corp. since February, 1974. Peter married Beth Luebbert in West Point, N.Y., in June of '74. . . . **Jeffrey J. Folinus** writes: "After completing my doctoral program, I ended up working with Harry Wolf (B.Arch. '60) in his aggressive young architecture firm, Wolf Associates. The firm has picked up several national architectural awards and now has a real-estate development subsidiary, TWFW Properties, which is my bailiwick." . . . **William Mammen** writes: "My wife Kay graduated from Brigham Young University this past April and I will begin work on my master's in Architecture at the University of Washington at Seattle this September. The purpose of the additional study will be to get teaching experience so that I may practice architecture and teach." . . . If any of you are doing things you think the rest of us would like to hear about, please write. I spent the summer clerking for a law firm in Houston and one in Dallas. My wife and I took a vacation to Kerrville, Texas, and to Santa Fe, N.M. Both are beautiful places. — **Hal Moorman,** Secretary, 3461 McFarlin, Dallas, Tex. 75205

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Joel Weisberg wrote: "I got my master's in astronomy (at the University of Iowa) in May and spent all summer studying for the physics comps which I just finished. I am spending the next few months becoming a human being again. Then December 1, I am going to Arecibo Observatory, Puerto Rico, for a year or so to do my Ph.D. thesis. I'll be studying the distribution of hydrogen in the Milky Way. Iowa City is a great place. My years here were a lot happier than my four at M.I.T. I'll miss this town a lot."

Dan Bloom is studying for an M.S. in broadcast management at B.U. . . . **Becky Donnellan** is at Wood's Hole doing postdoctoral work on the legal aspects of the ocean. . . . **Ric DiCapua** spent some time in South America trying to start a plastic packing company, which died for lack of funds. Contributions, I'm told, will be accepted. . . . **Ernesto Murillo** is in Urban Planning in Bogota. . . . **Ken Wayne** is at Harvard Business School. . . . **Betty Hutchins** has graduated from the Business School. . . . **Samer Khanachet** is in Beirut and is going into investment banking. . . . **Howard Haber** passed his prelims in physics at the University of Michigan. . . . **Eliot Singer** was married to Suzanne Sorkin on the Mt. Washington trail in Timberline Ravine in the White Mountains. . . . William, '69, and **Eunice Jean (Marks) Carson** are the parents of a son, William Waller Carson IV. Their daughter Eunice Rose is 2½. . . . **Uri Zoller** is at Haifa University-Oranim as head of the division of chemical studies in the School of Education of the Kibbutz Movement and is also at Everyman's University of Israel working on development of a science and technology curriculum for distant study. . . . Gary Lantner, '71, has been named general manager of the Boston South Terminal Corporation. The terminal is Logan's newest passenger facility. He and his wife **Janet (Saul) Lantner** are living in Lynn. Janet is working for Boston Edison. — **Dick Fletcher,** Secretary, 135 West St., Braintree, Mass. 02184

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Gary and **Ann McBain Ezzell** write of their Peace Corps activities. "We arrived in Malaysia on September 15, 1973, after a 24-hour charter flight from San Francisco. After the first shock of incredible heat and humidity wore off, we settled down to our Peace Corps training, during which we were given three and a half months to learn the national language, Bahasa Malaysia, and a little bit about the Malaysian school system and how to teach in it. We became official Peace Corps Volunteers on December 31, 1973, and by January 1 were speeding north in a careening intertown taxi, heading for Kuala Kangsar, Perak, our posting site (also the home town of the Sultan of Perak, who has a beautiful palace and one of the most lovely mosques in the world).

"Gary was sent to Sekolah Manengah Raja Perempual Kalson (more or less, 'Princess Kalson Secondary School'), a girls' school which was mostly English medium, with only three classes of Malay medium (two form V, one form IV). I went to Sekolah Manengah Jenis Kebangsaan Clifford (Clifford National Type Secondary School), also mostly English, but I had one class of form V and two classes of form IV. (Form IV is roughly equivalent to 10th grade in the U.S., but the academic standard is far lower.) Clifford, by the way, was almost exclusively a boys' school, except for a few form VI girls, whom I never taught.

"So there we were, and we spent the last school year, with all its interruptions of vacations and holidays and Sports Days and Speech Days and days off because the Sultan's brother-in-law died, trying to impart a little knowledge to students who often didn't care. There were a few who were even eager to learn, but they (as we all are) were handicapped by insufficient background. How can you teach completing the square to someone who doesn't have the faintest idea of how to manipulate equations?

"Anyway, we got through the year somehow, yours truly struggling along with the school's highly botany-oriented approach to biology, elementary math, and additional mathematics. This year I'll be going back to Clifford to continue with the new form V boys and possibly some new form IVs. Meanwhile, the Ministry of Education is shifting around the Malay Medium Science Stream, but they haven't gotten around to telling the teachers (including Gary) or the students involved where they're going to be. Typical.

"But don't take all the complaints too seriously. Except when we're hot and grouchy from the heat and ever-present humidity, we really like it here. The pace is much slower than in the U.S. (especially slower than at M.I.T.), which can be frustrating at times but in general leads to a more relaxing life. The people are wonderfully warm once you get them to let you down off the pedestal of the British colonialists (and sometimes to crawl up out of the mud after some of them have yanked you off that same pedestal).

"During the six-week vacation between school years (beginning mid-November, 1974), we took advantage of our proximity and went to Bali and Java. We can highly recommend Indonesia to anyone who manages to get to this part of the world. The food is good and cheap, lodging is cheap, the beaches are unbelievable, and the other scenery is magnificent.

"We'll be teaching in Kuala Kangsar at least until November, 1975 (unless we get kicked out), and may consider extending for another year, either in similar jobs or elsewhere in Malaysia. We're kind of homesick at times, but Malaysia is becoming more and more a part of us. (And, contrary to popular opinion, we're better off here financially than we would be in the U.S.!)"

Geoffrey Morris traveled to Europe and Asia Minor. When last heard from he was working on a book retelling some of the more believable of his experiences.

Pass That Proton Pistol, Buddy
or
I Don't Know Much About Physics But I Know What I Like

by Daniel P. Dern, '73

Well, here I am, with my M.I.T. degree, trying to be a science fiction writer. I've gone to the science fiction writers' workshop. I've taught a university course in science fiction. I've worked on computer manuals as a technical writer. One editor told me, "With your background, how come you're not out writing wonderful science fiction for me?"

I'm trying. Mostly the stories keep coming back to me, but that doesn't bother me (too much). It's not the rejection slips I mind, it's the reasons. Nobody's accusing me of bad writing (except for one or two editors noted for peculiar tastes, anyway). What do I hear most often, you ask? Bad plots? Clichéd gimmicks? Unbelievable characters?

No. I've got editors sending me kind, apologetic notes saying they're worried about my physics. For example, I've got this story called "Total Entropy Day." Does it collect notices on the order of "Go drive a truck," or, "Eat beans, kid"? No, instead my files turn up comments like "Why is the heat death of the universe happening now? Entropy isn't an overnight process. The story (therefore) is straight, unrationalized fantasy, and I want science fiction."

Wonderful. A physicist friend offered to write me up a justification for quantized entropic decay, which is still a topic where the questions outnumber the answers. But you don't sell stories to editors by attaching notes that testify how your science is kosher and legit.

Any shlump of an s-f writer can throw in all the "starwarps" and "tachyon vibrators" and "Antarean psi menaces" without a single reader raising a technical eyebrow. If you write utter nonsense, nobody will complain. But try a bit of the hard stuff, and all hell can break loose.

The slip that got to me worst came a while back. I went and wrote this long involved story, using all colors of holes, black hole bombs, toroidal singularities, the whole bag — strictly as literary metaphors, you understand — and sent the manuscript out, feeling that I'd not only used my physics properly but written a good story in the bargain.

I'm still not sure if it's a good story. Nobody's bothered to mention that.

But I've got a dandy full-page letter criticizing my physics. It seems that one editor I sent the story to has an upcoming article chock full of physics not yet out in the journals. (Mebbe it's not proved yet?) So I've got a rejection slip to the tune of, "Pretty good, Daniel, but black holes of less that stellar mass would seem to have an uncertain future, since Heisenberg's Law makes the area of uncertainty large enough — when the hole is small enough — to bleed the hole to death, and very quickly, too . . . so it seems unlikely that you'd actually have black holes hanging around for long." Etcetera.

But the last, demoralizing blow was what happened to the next story I sent this same editor. I had this old manuscript kicking around, full of blue mind-reading aliens who fell out of the sky and went native with stray Wellesley girls until their consciences got the better of them — I forget exactly how it went. It was a fairy tale, by my standards; I had carefully avoided using any science whatsoever, factual or fictitious.

The editor in question did not merely want to *buy* this story from me, he had the insidious, heart-felt impulse to say to me, "This is great! This is *real* science fiction!"

I come from the take-the-money-and-run school, so I kept my mouth shut and permitted him to buy the story from me. But it hurt. Am I not permitted to use science in my science fiction? Am I doomed to injecting pseudo-scientific hogwash into my manuscripts to make them salable? What's wrong with them all?

It doesn't seem quite right, but I guess that's the way it's going to be. And if anybody had a quarrel with the science in *this* article, I don't want to hear about it.

. . . **Thomas Stagliano** is a graduate student at the Institute and is still refereeing high school and college soccer. He received the Harold J. Pettegrove and Gold Awards for athletics. . . . **David Mark** has been working at Harvard Medical School and will return to the M.I.T. Nutrition Department this fall; he spends his weekends sailing at Marblehead. . . . **Bob Sutton** writes, "After a year back home as a first-year medical student at the University of North Carolina, I decided medicine wasn't quite my bag; so I returned to old cold Boston to follow a musical career and now sing the principal tenor roles for the Boston Light Opera, Ltd., a Gilbert and Sullivan repertory company in town." I attended a performance of "H.M.S. Pinafore" and "Trial by Jury" and found them to be a thoroughly enjoyable evening of entertainment which I would encourage you to see when you're in Boston.

— **Joy Judell,** Secretary / Treasurer, 1156 Commonwealth Ave. #58, Allston, Mass. 02134

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When I see former classmates they treat me rather strangely. I'm not sure if that is because I will put everything they say in this column or because I am so strange. Very peculiar. Some people feel that my column should be more controversial. Several others feel that it should go away. Ah, that is no matter — everything said passes over my head.

Well, I attended my second Annual Alumni Officers' Conference. I met **Sandra Yulke** there. She is going for her master's in geochemistry at M.I.T., which she will receive quite soon. Sandy was married to Bruce Loeffler in the M.I.T. chapel on May 24, 1975. Sandy also told me that **Paul Schindler** has been promoted to New England Bay Supervisor for United Press International. The rest of the Conference was fine — I met a lot of people, but no other former classmates.

Steve Jordan writes us: "Since graduation I've been working at Inland Steel Co. in East Chicago, Ind. My wife, Sue, will be graduating from college this June. Then in September I will be entering Harvard Business School. It will be good to get back to Boston."

I have received a letter from **Richard Sternberg**: "I'm about to enter my second year at University of Buffalo School of Medicine. I've moved to a new apartment closer to school and have furnished it completely. My roommate is Alan Schimmal, '75, who will be a freshman med student at

Three M.I.T. undergraduates joined the Alumni Association prematurely — as part-time employees in 1971. They worked there until — four years later — all three were members of the graduating class. An occasion for a party, thought Joseph J. Martori, Director for Alumni Services, who arranged for souvenir mugs, suitably inscribed, to honor the three popular employees. Left to right: Linda Forrester, who majored in mathematics and now attends the University of Vermont Medical School; Ilene Gordon, Vice President of the Class of '75, who has entered the Master's program at the Sloan School of Management after completing her bachelor's degree in mathematics; and Jennifer Gordon, Secretary-Treasurer of the Class of '75, who majored in biology and is studying for a Ph.D. in the Department of Nutrition and Food Science.

U/B this fall. Some notes from our classmates. **Dave Bernstein** picked up his master's in electrical engineering this past June and is now working for Thompson Ramo Wooldridge in Los Angeles. He has found a nice apartment and is enjoying himself. **Mary Anne Bradford** is still in Baltimore working for Bethlehem Steel. She is trying to get as much sailing in as possible." . . . From **David Godfrey**: "Currently I am working for the H. J. Heinz Company in Pittsburgh, Penn. I recently returned from a six-week assignment in sunny California producing apricots for use in baby food production. Debbie (my wife) and I thoroughly enjoyed traveling around California in our spare time. I had an opportunity to visit with fraternity brothers Jack Cavagnaro, '73, Bob Emerson, '73, **Jim Taul** and **Dave Vance** who all are enjoying San Francisco immensely. I also visited **Dave Withee** in Toledo, Ohio. Dave is currently masterminding the Junior Achievement conglomerate in south Toledo. I recently received a promotion at Heinz and now have responsibility for purchasing more than 20 million dollars worth of sweeteners — esp. sugar and corn sweeteners. I spend much time analyzing the world sugar market in search of good buying opportunities. The job is truly fun and action packed. I'll probably be at Heinz as long as I can describe my work in that way." . . . **John E. Plum** writes: "I'm finishing up the Commercial Bank Management Training Program in September. Currently in Corporate Research analyzing banks and drug companies. Hope to be in money markets in the fall."

W. Thad Byrd is now Assistant to the Director of the M.I.T. Educational Council. For the year before he served as an intern in the Admissions Office and was a student employee in the Financial Aid Office. The Educational Council is a nationwide organization of more than 1,000 M.I.T. alumni who counsel high school students interested in science or engineering-based careers.

I met **Bob Lee** on the streets of Cambridge a while ago. He is going for his M.D. at the Einstein College of Medicine. **Harold Milstein** is in the same program with him. Bob also told me that **Jeff Ng** is going to Princeton University for his master's in architecture.

As usual, I can say a lot more, but have nothing more to talk about. — **Dennis Dickstein,** Secretary-Treasurer, 16A Forest St., Apt. B1, Cambridge, Mass. 02140

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My apologies if this column seems brief and somewhat rushed. The deadline couldn't have come at a worse time for me, schoolwise. Anyway, here goes.

I paid a visit to Mr. Weatherall in the Career Planning and Placement Office and he was nice enough to provide me with some statistics on the class of '75. I thought a table of the results might be of some interest to you. Also, of those of us who responded to the C.P. and P. questionnaire, 58.4 per cent of us are in debt to the Institute, the median debt being in the range of $4001 to $4250. Sorry for this unpleasant reminder.

Well, at least two members of our class are financially set for awhile. **Dean E. Calcagni** and **Thomas F. Fleischhauer** have been named as recipients of an Armed Forces Health Professions Scholarship. They received their commissions through the M.I.T. Army and Air Force R.O.T.C. programs, respectively. Lt. Calcagni is studying at the University of Vermont Medical School and Lt. Fleischhauer is attending the University of Virginia Medical School. I understand that the scholarships cover medical school tuition, lab fees, the cost of books, and a stipend to boot. Congratulations! That's quite a haul.

I ran into **Diane McKnight** the other day and when I asked her if she had any news to relate, she told me that she and Larry Esposito, '73, had been married this past summer. Diane is presently a graduate student in the Department of Mechanical Engineering at M.I.T. . . . For those of you who may have been wondering what **Cliff Wald** is doing these days, wonder no more. Cliff is working for the Dreyfus Company in Minneapolis, Minn., giving his economics background a workout in the grain trading business. In two years' time he will return to Cambridge to attend Harvard Business School.

Placement by Career: Classes of Sept. '74, Feb. '75, and June '75

	Per cent of graduates
Teaching (school, college or university):	
M.I.T.	0.3
Elsewhere	0.3
Academic and nonprofit research	1.8
Postgraduate study:	
M.I.T.	21.8
Elsewhere	41.9
Industry, Business, Private firms	13.1
Nonprofit organizations	2.1
Government	1.4
Armed Services	0.9
Foreign student returning home (any occupation)	4.3
Miscellaneous	2.7
Unsettled, unemployed	9.4
Total of known situations: (703)	100

I regret having to report that our classmate **Timothy Holm** died on June 20, 1975. He was attempting a complicated dive in a hang glider. Tim was a humanities major from Pleasant Hill, Calif.

That's all the news for this column. Here's hoping you all have a happy holiday season and that you might find time to drop me a line to let me know what you're doing. — **Jennifer Gordon,** Secretary-Treasurer, 5 Centre St., Cambridge, Mass. 02139